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Capital Taxation and Accumulation in a Life Cycle Growth Model

By LAWRENCE H. SUMMERS*

Almost all of the serious economic work on savings decisions within the past decade has relied on some variant of the life cycle hypothesis in which savings arise out of individual choices of an optimum lifetime consumption path. This paper reexamines the incidence and welfare consequences of capital income taxes within a realistic life cycle model. The results suggest that the elimination of capital income taxation would have very substantial economic effects. For example, a complete shift to consumption taxation might raise steady-state output by as much as 18 percent, and consumption by 16 percent. The long-run welfare gain from such a shift would for plausible parameter values exceed $150 billion annually. Stated somewhat differently, shifting to consumption taxation would raise the lifetime utility of the representative consumer by the equivalent of about six years' income in the new steady state. These estimates dwarf estimates of the static welfare cost of taxation, and significantly exceed even extreme previous estimates of the dynamic loss.

This study departs from earlier analyses of the effects of taxes on capital income in several respects. Probably the most important difference between this treatment and most preceding ones lies in the assumptions about the interest elasticity of saving. It is shown below that the common two-period formulation of saving decisions yields quite misleading results. A more realistic model of life cycle savings demonstrates that, for a wide variety of plausible parameter values, savings are very interest elastic. This implies that shifting away from capital income taxation would significantly increase capital formation, making possible long-run increases in consumption.

Many studies of the welfare effects of capital income taxation have ignored the general equilibrium effects of increased capital formation. In an economy with life cycle savings, there is no presumption that the undistorted growth path corresponds to any sort of social optimum. As Peter Diamond has shown, life cycle savings can lead to a steady-state capital intensity either greater or less than the Golden Rule level. More generally, it is clear that there is no reason to believe that a life cycle economy will maximize any particular intertemporal social welfare function. A fundamental tenet of welfare evaluation is that preexisting distortions must be considered in evaluating the consequences of tax changes. The results presented in this paper take explicit account of the nonoptimal character of the no-tax steady state. This explains in large part why such a sizeable welfare effect of capital taxes is found. In an economy far from the Golden Rule level of capital intensity, there are substantial gains in steady-state consumption achievable through increased capital formation.

Section I of the paper examines the aggregate savings function in a continuous-time life cycle framework. The second section clarifies the differences between wage and consumption taxes. An aggregate production function is added to complete the model in the third section. The effects of changes in capital taxes on both steady-state incidence and welfare are considered within a general equilibrium framework. The final section of the paper discusses some implications of the results and suggests areas which appear to warrant further study.

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I. The Aggregate Savings Function

In all studies of the effects of capital income taxation, the interest elasticity of the aggregate savings rate emerges as a key parameter. This parameter is also central to questions ranging from the potency of monetary policy to the appropriate discount rate on public investments projects.[1] Both empirical and theoretical considerations have led most economists to conclude that the interest sensitivity of aggregate savings is likely to be quite small. This section examines the implications of the well-known life cycle hypothesis for the interest elasticity of aggregate savings. It is shown that the theory when formulated realistically implies interest elasticities well in excess of unity.

Most commonly, the impact of capital income taxes has been considered within a two-period framework, in which all income is received within the first period.[2] That is, the representative individual is assumed to maximize an intertemporal utility function of the form $U(C_1, C_2)$ subject to a lifetime budget constraint:

$$C_1 + \frac{C_2}{1+r} = W_1 \tag{1}$$

where W_1 represents labor income in the first period. It can be shown[3] that the interest elasticity of savings depends on the elasticity of substitution between present and future consumption. If the elasticity is greater than one, savings respond positively to the interest rate, while an elasticity less than one implies a negative savings response. In the knife-edge Cobb-Douglas case where the elasticity of substitution is one, savings are independent of the interest rate. Since the last case seems reasonable, and theory does not offer an unambiguous verdict on the sign of the interest effect, it is frequently held that savings are likely to be interest insensitive. This notion is supported by verbal reference to conflicting substitution and income effects. Martin Feldstein (1978) has shown that in a two-period setting, savings may be usefully viewed as expenditure on future consumption. The case where savings are insensitive to the interest rate occurs when the price elasticity of demand for future consumption is one.

The usual two-period formulation of the savings decision obscures two important aspects of reality. In all modern theories, saving is carried on to provide for future consumption. All savings are eventually dissaved. Net positive savings arise only because the young who save are more affluent and numerous than retired dissavers. In order to realistically model the determination of net savings, it is necessary to take account of the dissaving of older generations. This is not usually done in two-period formulations of the problem which treat the savings decision as equivalent to the choice of C_1.

The second difficulty with the usual two-period formulation is that it obscures the role of future labor income. In a multiperiod setting, the endowment W_1 in equation (1) represents the present value of future labor income. When the interest rate rises, this endowment declines as future income is more heavily discounted. Even in the Cobb-Douglas case where the consumption propensity out of wealth is independent of the interest rate, consumption will fall as the interest rate rises through what might be called a human wealth effect.[4] With income constant, an increase in savings is implied. Since savings represent only a small fraction

[1] Michael Boskin discusses the implications of the interest elasticity of savings for several aspects of capital accumulation. He finds that even an elasticity of .4 can have an important impact. The analysis below suggests .4 is likely to be a significant underestimate of the true elasticity.

[2] Exceptions include David Levhari and Eytan Sheshinski, and Robert Hall. Levhari and Sheshinski's analysis is confined to a partial equilibrium framework. Hall's study parallels this one in many respects but reaches radically different conclusions about the welfare consequences of capital taxes. Using a life cycle model without retirement, he does conclude that aggregate savings are likely to be quite interest elastic on grounds quite similar to those considered here.

[3] The two-period consumption savings decision is extensively discussed in Martin Feldstein and S. C. Tsiang.

[4] This terminology may be somewhat misleading. Increases in the interest rate to reduce the value of consumers' endowment measured in terms of first-period consumption. However, in general, they broaden the set of feasible consumption paths and raise welfare.

of income, even a small effect on consumption can translate into a large effect on savings.

In order to realistically take account of human wealth and the difficulties of aggregation, it is necessary to formulate a model in which many generations coexist at any instant. This is most easily done in continuous time. Models of the type outlined below have been used by James Tobin, Hall, M. J. Farrell and Laurence Kotlikoff to explore various aspects of life cycle savings. Let us first consider individual and then aggregate savings.

Individuals choose a consumption plan to maximize an intertemporal utility function, subject to a lifetime budget constraint.

$$(2) \qquad max \int_0^T U(C_t)e^{-\delta t}\,dt$$

subject to

$$\int_0^T C_t e^{-rt}\,dt = \int_0^{T'} W_t e^{-rt}\,dt$$

where T represents the certain date of death,[5] T' the age of retirement, δ is a discount factor, and W represents labor income. In order to render the problem tractable, I adopt a constant elasticity utility function,[6] and assume that at any instant all workers receive the same wage which rises exponentially at rate g.[7] With these assumptions the Lagrangian for the individual maximization problem becomes

$$(3) \qquad \int_0^T C_t^{\gamma} e^{-\delta t}\,dt - \lambda\left[\int_0^T C_t e^{-rt}\,dt - \int_0^{T'} W_0 e^{(g-r)t}\,dt\right] \text{ if } \gamma \neq 0$$

$$\int_0^T \log C_t e^{-\delta t}\,dt - \lambda\left[\int_0^T C_t e^{-rt}\,dt - \int_0^{T'} W_0 e^{(g-r)t}\,dt\right] \text{ if } \gamma = 0$$

where γ is the elasticity of the marginal utility function. The expression $1/(1-\gamma)$ corresponds to the intertemporal elasticity of substitution in consumption. Solving the individual maximization problem (3) yields the conditions:

$$(4a) \qquad C_t = C_0 e^{[(r-\delta)/(1-\gamma)]t}$$

$$(4b) \qquad C_0 = \frac{W_0\left(e^{(g-r)T'}-1\right)\left[\left(\frac{r-\delta}{1-\gamma}\right)-r\right]}{\left(e^{((r-\delta)/(1-\gamma)-r)T}-1\right)(g-r)}$$

It is clear from (4) that the slope of the age-consumption profile rises with the interest rate, with the sensitivity depending on γ. In order to find aggregate consumption, it is necessary to aggregate over the consumption of all persons alive at a point in time. Using equations (4) the consumption of persons of each age can be calculated as a function of their initial wage. The relative number of persons of each age depends on the population growth rate n. The larger is n, the greater the fraction of the population which is young. By adding up consumption at each age, weighted by relative population size, and initial wage W_0, total consumption of the population may be calculated.

From aggregate consumption, it is possible to calculate the savings rate out of labor income using the steady-state assumption. Steady-state growth implies that

$$(5) \qquad (n+g)K = wL + rK - C = S$$

where n is the rate of population growth.

[5]In this paper, perfect certainty is assumed throughout. Robert Merton has demonstrated in a continuous-time framework that allowing for uncertainty does not alter the character of the optimal intertemporal consumption plan. However, it might importantly affect the analysis of tax changes, which alters both the return and risk from savings.

[6]The constant elasticity utility function with a constant discount rate is capable of generating smooth consumption paths with any slope. It is not clear that the additional range of behavior admitted by more general utility functions is very plausible. In any event a "smooth" consumption stream is a central assumption of all life cycle theories of savings.

[7]It would be desirable to explicitly incorporate an instantaneous age earnings profile. However, Alan Blinder argues that because the profile rises and then declines after about age 50, the approximation adopted here is not likely to be too inaccurate.

Solving equation (5) it is apparent that

$$(6) \qquad \frac{S}{WL} = \frac{(n+g)\left(\frac{C}{WL}-1\right)}{r-n-g}$$

Substituting for C/WL in (6) yields the aggregate savings function:

$$(7) \qquad \frac{S}{WL} = \left(\frac{r-\delta}{1-\gamma}-r\right)\left(e^{(g-r)T'}-1\right)$$

$$\times\left(e^{((\frac{r-\delta}{1-\gamma})-g-n)T}-1\right)(n)(n+g)$$

$$\div\left(\left[\frac{r-\delta}{1-\gamma}-n-g\right](g-r)\left(e^{(\frac{r-\delta}{1-\gamma}-r)T}-1\right)\right.$$

$$\left.\times(1-e^{-NT'})(r-n-g)\right)-\frac{n+g}{r-n-g}$$

It is noteworthy that (7) shows that the life cycle hypothesis gives rise to a steady-state aggregate savings function which may be represented by a variable propensity to save out of labor income, and a zero-savings propensity out of capital income. The life cycle hypothesis thus gives rise to a savings function which is quite different than that usually assumed in growth models which allow different savings propensities out of different types of income.

It is clear from (7) that the relationship between savings and the interest rate is complex and depends on all of the other parameters in the model. In Table 1 the savings rate, defined as S/WL, and interest elasticity of aggregate savings η_r, evaluated at various values of the interest rate, are reported for plausible parameter values. It is assumed that population grows at a 1.5 percent per annum, productivity increases by 2 percent per annum, and that individuals live fifty-year economic lives with retirement at age 40. Somewhat arbitrarily, a 3 percent utility discount factor was chosen.

TABLE 1—THE INTEREST ELASTICITY OF AGGREGATE SAVINGS

	Value of r		
	.04	.06	.08
$\gamma=.5$			
η_r	3.71	2.26	2.44
S/WL	.121	.274	.451
$\gamma=0$			
η_r	3.36	1.89	1.87
S/WL	.068	.142	.210
$\gamma=-.5$			
η_r	3.09	1.71	1.54
S/WL	.049	.096	.135
$\gamma=-1$			
η_r	2.87	1.59	1.37
S/WL	.038	.073	.099
$\gamma=-2$			
η_r	2.38	1.45	.122
S/WL	.028	.048	.063
$\gamma=-5$			
η_r	.741	1.09	1.18
S/WL	.014	.019	.025

Note: The calculation assumes $n=.015$, $g=.02$, $T'=50$, $T=40$, and $\delta=.03$. The savings rate is measured as a fraction of labor income.

The results universally support a high interest elasticity. In the plausible logarithmic utility case, the interest elasticity of the savings rate varies from 3.36 at 4 percent to 1.87 at 8 percent. This case also generates the most reasonable values for the aggregate savings rate. The table demonstrates the unimportance of the elasticity of substitution between present and future consumption. For example, at an interest rate of .06, the elasticity of saving varies only from 2.26 when $\gamma=1/2$ to 1.09 when $\gamma=-5$. The insensitivity of the elasticity to the level of γ reflects the fact that the "reduction in human wealth" effect is much more important that the substitution effect of interest changes. The basic conclusion, a significant long-run interest elasticity of aggregate savings, is quite robust to changes in all of the parameter values. While very low values of γ could generate low or even negative savings elasticities, they would also give rise to unrealistic savings propensities, unless the other parameter values are set to implausible levels. Almost any plausible life cycle formulation is likely to imply a high long-run elasticity of savings

with respect to the interest rate. It seems fair to conclude that two-period analyses of the effects of capital taxes are likely to be quite misleading. Efforts to use empirical savings elasticities to estimate elasticities of substitution between present and future consumption are very misguided, unless the "human wealth effect" is explicitly considered.

So far it has been assumed that saving is motivated only by the desire to provide for retirement consumption. This assumption has been challenged by Kotlikoff and myself (1979). We suggested that the life cycle hypothesis could account for only a relatively small fraction of total savings. Our results indicate that a significant fraction of capital formation is motivated by a desire to leave bequests. Assuming that consumers bequeath a constant proportion of lifetime income would not have any important impact on the results. Robert Barro has shown that if bequests arise from maximization of a utility function in which the utility of future generations appears as an argument, the intertemporal decision problem is radically altered. Essentially, this case is equivalent to treating each consumer as if he had an infinite horizon, since he internalizes the welfare of future generations. Miguel Sidrauski has shown that, in this case, the long-run savings rate is infinitely interest elastic as the capital stock is always driven to a "modified Golden Rule" level. Thus allowing for such bequests would strengthen the conclusions reached here.

Interest elasticities of savings as high as those reported in Table 1 appear at first blush to be flatly contradicted by the available empirical studies which have found only small interest rate effects. Beyond the standard problems of errors in variables,[8] and specification error,[9] there is an important reason to expect interest rate effects in usual empirical specifications to differ from those calculated here. At issue here is the change in the savings rate out of income when the interest rate changes. Usually, in empirical work, wealth is held constant. Since interest rate changes exert their effect in part through changes in wealth, this procedure is likely to obscure the impact of interest rates. The importance of this question is apparent in Boskin's careful study of the interest elasticity of savings. Its results imply a direct savings elasticity of about .4, with respect to interest rate changes, and about 2.8 with respect to changes in wealth. Thus, if the interest elasticity of wealth is .5, the "full effect" interest elasticity of savings is 1.9, which is within the range suggested here.[10]

The discussion in this section establishes a prima facie theoretical case for a high interest elasticity of savings. This conclusion appears to follow almost ineluctably from a realistic life cycle formulation.[11] This implies that the frequent assumption of a constant savings rate in analyses of economic growth may be quite inaccurate. It also indicates that the case where savings depend negatively on the interest rate, which yields pathological results in many models, can legitimately be ruled out. A high interest elasticity of savings has important implications for almost all questions bearing on capital accu-

[8]Typically, studies have used the nominal interest rate as a measure of the return on savings. Only Boskin has used the more appropriate real after-tax rate. Even this series is flawed because the long-term interest rate accurately reflects the return on only a small part of savings. Satisfactory measures of the expected return on equity, homes, and durable goods are nonexistent. Since the interest rate has been fairly highly correlated with income and wealth over the past forty years, even small errors in interest rate measures could cause very significant underestimation of interest rate effects.

[9]Life cycle theories imply that the age structure of the population, the rate of growth of output, life expectancy, and expected retirement age all affect the savings rate. None of these variables has been included in time-series savings equations.

[10]If all wealth were held in the form of consols, the elasticity would be one; if it were all held in short assets, it would be zero. Common stock fluctuations which account for most of the variation in wealth are known to be caused by interest rate changes. The simplest valuation model in which the *P-E* ratio is set equal to the interest rate would imply an elasticity of one. Of course, with changes in taxes, and pretax profitability the actual situation is much more complex. The assumption of a .5 elasticity seems conservative.

[11]A fuller effort to reconcile the theoretical calculations with the empirical evidence may be found in my earlier paper which treats issues surrounding the short-run response of savings to both transitory and permanent changes in the interest rate.

mulation. Its impact on estimates of the incidence and welfare consequences of capital taxation are examined in some detail in succeeding sections of this paper.

II. Alternatives to Capital Taxation

It is widely believed that taxation of labor income is equivalent to consumption taxation as long as there are no bequests. This section demonstrates the extremely restricted sense in which this proposition is correct, and shows that wage and consumption taxation in a general equilibrium setting have different effects in both the short and long run.[12] It follows that even if consumption taxation is optimal, replacing capital taxes with taxes on labor income may not be desirable.

The sense in which consumption and labor income taxation are equivalent is easily demonstrated by specifying the individual's budget constraint in each case. With wage taxation the budget constraint is

$$(8)\quad \int_0^T C_t e^{-rt}\,dt - \int_0^{T'} W_t(1-t_L)e^{-rt}\,dt = 0$$

The budget constraint with consumption taxation takes the form

$$(9)\quad \int_0^T \frac{C_t}{1-t_c} e^{-rt}\,dt - \int_0^{T'} W_t e^{-rt}\,dt = 0$$

where t_c is the ad valorem tax rate on consumption. It is apparent that if $t_c = t_L$, the two tax regimes offer consumers equivalent choice sets, and, in a present value sense, raise equal revenues. Since consumers have the same opportunity set, they will choose the same optimal consumption path under each regime. It is in this restricted sense that wage and consumption taxes may be said to be equivalent.

In a life cycle setting, savings arise because the desired consumption stream does not match the path of income. Since the timing of tax collection is very different under wage and consumption taxes, they have very different effects on savings. Savings at an instant t are the difference between income and consumption. Hence with consumption taxation savings may be written as

$$(10)\qquad S_t = W_t + rA_t - \frac{C_t}{1-t_c}$$

while under wage taxation savings are

$$(11)\qquad S_t = (1-t_L)W_t + rA_t - C_t$$

Quite clearly there is no reason why these expressions need be equal period by period. Consumption taxation extracts revenue later in the individual's lifetime than does wage taxation and so causes more savings in the younger years. The difference in the aggregate savings rate between the two types of taxes depends on the age structure of the population. But it is clear from (10) and (11) that there is no a priori reason to expect equal savings rates.

Equations (9) and (10) illustrate an important property of consumption taxation. It is completely neutral with respect to the savings rate. It is clear from (9) that for any homothetic utility function along the optimal path $C_t/1-t_c$ will be the same for any value of t_c. This implies, using (10), that savings at all ages and hence aggregate savings are also unaffected by the tax rate. Equation (11) shows that this property does not hold for taxes on wage income, since the time path of savings is altered. In fact, as the results in the next section demonstrate, wage taxation significantly reduces capital intensity relative to consumption taxation.

A second important difference between wage and consumption taxation lies in the government budget constraint. The usual argument demonstrating the equivalence of wage and consumption taxation assumes that the government raises the same present value of revenue from each individual under both regimes. A somewhat plausible requirement is that in each period the government raises

[12] Feldstein (1978b) has examined the transition away from capital taxation. His analysis underscores the importance of compensating the older generation in shifting to consumption taxation, but does not emphasize the different effects of consumption and wage taxation in the long run.

the same amount of revenue from the total population under each tax.[13] If G is the government's revenue requirement, the budget constraint under wage taxation is

$$(12) \qquad \int_0^{T'} e^{-ns} W(1-t_L)\, ds = G$$

while under consumption taxation the constraint is

$$(13) \qquad \int_0^{T} e^{-ns} C_s \frac{t_c}{1-t_c}\, ds = G$$

These equations do not imply that $t_c = t_L$. The reason for this is straightforward. The individual is discounting at rate r in calculating the present value of taxes paid at different ages. On the other hand, the government in steady states implicitly discounts at n, the rate of population growth. As long as $r > n$, the government can meet its budget constraint, and reduce the present value of the taxes each individual must pay by postponing the extraction of taxes. As noted above, consumption taxes postpone tax payments relative to wage taxes. Hence, with consumption taxation it is possible to reduce the steady-state present value of taxes paid by the representative individual.

Feldstein (1978b) has observed that wage and consumption taxes involve quite different transition paths. To see this, consider the sudden imposition of a consumption tax. Consumers of all ages are equally affected. On the other hand, imposition of a wage tax has no effect on the retired segment of the population. Loosely speaking, the consumption tax is less burdensome on workers in the steady state, because it taxes more heavily those who are alive at the moment when it is imposed.

The analysis in this section indicates that it is inappropriate in either the short or long run to regard consumption and labor income taxation as equivalent even in the absence of bequests. Since they give rise to different age-savings patterns, they do not have the same effect on steady-state capital intensity. Of equal importance, the rates which are necessary to meet a constant government budget constraint will differ between the two taxes. In the next section, both wage and consumption taxes are considered as alternatives to capital income taxation.

[13] David Bradford emphasizes the importance of this "balanced budget" requirement. He argues that without such a requirement the government by running surpluses or deficits can control the level of the capital stock given any tax structure. The "real world" feasibility of this sort of policy seems unclear.

III. Steady-State Comparisons of Tax Alternatives

In this section, the effect of replacing capital income taxes with wage and consumption taxes is examined by comparing steady states. In order to make a general equilibrium comparison of tax alternatives, it is necessary to join a production side to the life cycle savings model examined in the first section. James Tobin and Robert Hall have shown this can be done diagramatically.

Above, it was shown that life cycle savings gives rise to a savings-labor income ratio which is a function of the interest rate. Under the steady-state assumption, this can be readily converted into a capital-labor income ratio by dividing by the growth rate. This is represented by the SS curve in Figure 1. The production function also implies a relationship between the capital-labor income ratio and the interest rate. This is plotted as PP in Figure 1. (In the Cobb-Douglas case it is a rectangular hyperbola.) In the no-capital tax case, equilibrium occurs where the curves cross. Now consider the effect of imposing a tax on capital income. This drives a wedge between the gross interest rate determined by the production function and the net rate received by savers. The new equilibrium occurs where the difference between the interest rate along the PP and SS curves is equal to the tax. It is clear from the figure that as long as savings respond positively to the interest rate, imposition of a capital tax raises the gross return and reduces the net return on capital. Hence capital taxes will be partially but not completely shifted.

The characteristics of a steady state can be calculated numerically by finding the value

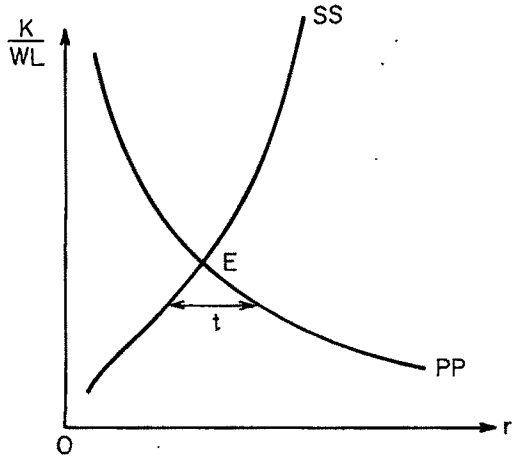

FIGURE 1

of K for which

$$(14)\quad \frac{S(F_L(1-t_L), F_K(1-t_K))}{n+g} = \frac{K}{F_L L}$$

where $S(\cdot)$ represents the aggregate savings function provided in (7). Once the steady-state value of K is found, the levels of output and consumption as well as factor prices can be found from the steady-state condition (5) and the production function.

In calculating the effects of tax changes, it is necessary to make assumptions about parameter values. The parameters of the savings function are the same as those assumed above. In the results reported below, logarithmic utility ($\gamma=0$) is assumed. As will be shown, the main conclusions are not sensitive to this assumption. Tax changes are analyzed with elasticities of substitution in production of 1 and 1/2.[14] In each case, parameters of the production function were chosen so that the capital share was .25. The appropriate value of the tax rates is not easy to determine. The capital tax is presumed to represent the combined effect of corporate taxes, individual income taxes on dividends and interest income, and property taxes. Recent evidence (see the 1980 paper by Feldstein and myself) suggests that inflation has substantially raised the effective rate of all these taxes. A value of .5 for the capital income tax rate seems conservative on the basis of these considerations.[15] A tax rate of .2 on labor income is also assumed. These assumptions imply that government revenues equal 27.5 percent of *GNP*, which is within the empirically reasonable range.

The model was solved for the steady state under this tax regime. The steady state was then recalculated with the capital tax replaced by a wage tax with exactly equal revenue yield and with both the interest and labor income taxes replaced by a consumption tax. Thus, all the analysis here is carried out within a differential incidence framework, in which alternative sources of the same amount of government revenue are contrasted. Representative results are presented in Table 2.

It is interesting to note that the base calculation shown in column 1 corresponds quite accurately to the actual American economy. The gross of tax return on capital in both cases mirrors the average return on capital of 11 percent estimated by Feldstein and myself (1977). The savings rate of about 8.5 percent is close to the historical rate.

The shift away from capital taxation has very substantial effects. In the Cobb-Douglas case, steady-state income rises by about 14 percent if wage taxation is used and 18 percent with consumption taxation. The increase in income occurs because the high interest elasticity of savings leads to a large increase in capital intensity. Indeed the capital-output ratio rises by almost 75 percent in the consumption tax solution. This increase drives down the gross return on capital from 10.5 to 6.1 percent. Consequently the owners of capital do not benefit greatly from the removal of the capital tax. On the other hand, the increase in capital intensity raises the gross wage. The increase

[14]These numbers represent bounds on the true elasticity. Cross-section estimates typically imply that σ is close to 1, while time-series estimates suggest an elasticity close to 1/2. Robert Lucas, after contrasting these approaches, concludes that the time-series estimates are to be preferred.

[15]It is the effective marginal rate which is at issue here. This will depend critically on the method of financing of marginal investment. Joseph Stiglitz has argued that complete debt financing at the margin would imply a zero effective rate. This view has been challenged by Feldstein, Jerry Green, and Sheshinski, among others.

TABLE 2—COMPARISON OF STEADY STATES: INCOME, PAYROLL, AND CONSUMPTION TAXES

	Current System		Payroll Tax		Consumption Tax		Percent $\Delta(1-2)$		Percent $\Delta(1-3)$	
	$(\sigma=1)$	$(\sigma=1/2)$	$(\sigma=1)$	$(\sigma=1/2)$	$(\sigma=1)$	$(\sigma=1/2)$	$(\sigma=1)$	$(\sigma=1/2)$	$(\sigma=1)$	$(\sigma=1/2)$
R_G	0.105	0.112	0.069	0.066	0.061	0.056	−42.4	−51.9	−53.7	−66.3
R_N	0.053	0.056	0.069	0.066	0.061	0.056	26.1	16.2	14.3	0.4
W_G	1.000	2.018	1.155	2.420	1.202	2.526	14.4	18.1	18.3	22.4
W_N	0.800	1.614	0.788	1.604	1.202	2.526	−1.6	−0.6	40.0	44.0
Y/L	1.334	2.841	1.541	3.111	1.604	2.179	14.4	9.1	18.3	11.2
C/L	0.856	1.769	0.977	1.928	1.004	1.955	13.1	8.6	15.9	10.0
K/Y	2.373	2.589	3.652	3.375	4.117	3.653	42.4	26.4	53.7	34.1
S/Y	0.083	0.091	0.128	0.118	0.144	0.128	42.4	26.4	53.7	34.1

Note: These calculations assume $n=0.015$, $g=0.02$, $\gamma=0.001$, and that $t_W=0.2$ and $t_r=0.5$ in the current system.

is large enough to almost completely offset higher taxes on labor income. The net wage falls by less than 1 percent when capital taxes are replaced by the payroll tax.

Since the gross rate of return in the equilibrium with capital taxes is well above the Golden Rule level, steady-state consumption is increased as capital intensity rises. When capital taxes are replaced by wage taxes, consumption rises by 14.2 percent, while it rises by 17.1 percent with consumption taxes. Of course these gains cannot be interpreted as a measure of the steady-state welfare increment from eliminating capital taxes. The appropriate criterion is the utility of the representative individual.

The steady-state change in the welfare of the representative individual can be expressed as a fraction of lifetime income as follows. In a steady state, individual welfare V is given by

$$V=\int_0^T C^\gamma e^{-\delta t}\,dt \tag{15}$$

Substituting using equation (4) yields an expression for lifetime utility as a function of lifetime income, H, and the net interest rate.

$$V(H,r_N)=H^\gamma\left[\frac{(r_N-\delta)}{\left(e^{\frac{(r_N-\delta)T}{\gamma-1}}-1\right)}\right]^\gamma \times\left[\frac{\left(e^{\frac{r_N-\delta}{\gamma-1}}-1\right)(\gamma-1)}{\gamma(r_N-\delta)}\right] \tag{16}$$

where $r_N=r(1-t_K)$ the net interest rate, and human wealth H is given by

$$H=\frac{W(1-t_L)(e^{(\delta-r_N)T'}-1)}{(g-r_N)} \tag{17}$$

Welfare V can be compared across alternative steady-state paths. However, in order to yield a meaningful result, it is necessary to express the welfare difference in operational units. This may be done most easily by calculating the percentage change in lifetime earnings in the base steady state which would be necessary to yield the welfare level reached in the altered steady state. To do this, it is necessary to solve the equation:

$$V\left(H^1(1+L),r_N^1\right)=V\left(H^2,r_N^2\right) \tag{18}$$

for L, which is a measure of the welfare difference between the two steady states. Unlike most welfare loss calculations this approach does not rely on differential approximations. It is accurate for changes of any size.[16]

Table 3 presents the steady-state welfare gains from the tax changes, outlined above for alternative utility and production functions. The results indicate the potential for large gains from eliminating capital taxes. In the intermediate case, where $\gamma=0$, instituting a payroll tax would raise welfare by the

[16] Green and Sheshinski have demonstrated the danger of extrapolating differential approximation to tax effects over large ranges.

TABLE 3—THE STEADY-STATE WELFARE COST OF CAPITAL INCOME TAXATION

	$\gamma=0.5$	$\gamma=0.001$	$\gamma=-1$
	Percentage Change in Steady-State Consumption		
		$(\sigma=1)$	
Payroll Taxation	12.7	13.1	13.3
Consumption Taxation	14.0	15.9	17.4
		$(\sigma=\frac{1}{2})$	
Payroll Taxation	6.1	8.6	12.9
Consumption Taxation	6.5	10.0	17.2
	Welfare Gain (expressed as a percentage of lifetime income)		
		$(\sigma=1)$	
Payroll	7.0	4.9	1.4
Consumption	11.2	11.7	11.6
		$(\sigma=\frac{1}{2})$	
Payroll	3.8	3.5	1.1
Consumption	6.2	9.4	16.2

Note: Calculated assuming that $n=0.015$, $g=0.02$, and that $t_w=0.2$ and $t_r=0.5$ in the current system.

equivalent of almost 5 percent of lifetime income, while consumption taxes would raise welfare by about 12 percent, or almost five years' earnings. Applying these figures to American aggregates yields huge annual flows, about $80 billion in the former case and approximately $200 billion in the latter.

These large gains are smaller than the gains in steady-state consumption shown in the top half of the table. This is because the increase in the net interest rate leads individuals to consume later in their lifetimes, reducing the increases in welfare. There are two reasons why the welfare gain tends to be smaller for lower values of γ. First, a lower value of γ implies a lower savings elasticity, and hence less gain from approaching the Golden Rule. Second, a small γ implies only a small distortion of the shape of the consumption path.

A very surprising feature of the results is the large difference in steady state welfare between consumption and wage taxes. For example, in the Cobb-Douglas $\gamma=0$ case, the steady-state gain in welfare arising from shifting from labor to consumption taxation approaches $100 billion a year. The greater welfare under consumption taxes occurs for two reasons. As noted in the previous section, capital intensity is higher with consumption taxes, which raises welfare by making possible a higher level of steady-state consumption. The second reason is probably more important. Consumption taxation reduces the present value of the taxes each individual pays during his lifetime. This occurs because the tax burden is increased on those alive during the transition to consumption taxation. Hence the steady-state comparison may be a poor indicator of the efficiency advantages of consumption taxation.

The calculations presented here indicate that partial equilibrium calculations of the welfare consequences of capital taxes are likely to be very misleading. Such calculations focus on the welfare loss which takes place because the taxation of interest distorts the shape of the consumption profile. The results here indicate this effect is of only minimal importance. Since in a realistic life cycle model, savings are very interest elastic, changes in capital taxes have only a small effect on the net interest rate. Thus partial-equilibrium analysis by assuming a constant *gross* interest rate greatly overstates the importance of intertemporal substitution effects.

The important effect of removing capital taxes on welfare is not captured in partial-equilibrium analyses. The large increase in capital which results raises real wages and leads to a larger level of sustainable consumption. It is the interaction of increased capital intensity with the preexisting distortion of a significant divergence from the Golden Rule, which causes the removal of capital taxes to lead to such large gains in these calculations.

There are two potentially important difficulties with the analysis. First, no allowance is made for variable labor supply. The distortion of the labor-leisure choice is not considered in evaluating the welfare consequences of wage taxation. It seems unlikely that relaxing the assumption of inelastic labor supply would alter the results in an important way. The general equilibrium effects described above imply that shifting to wage taxation changes real wages only slightly. Hence, labor supply is likely to be little affected. Allowing for intertemporal variation in labor supply might actually increase the estimated gain from reducing capital taxes. Similar conclusions apply to consumption taxation.

Second, the analysis here is confined to steady-state comparisons. Higher steady-state consumption is achieved only at the expense of consumption during the transition to the new steady state. Hence, the costs of transition must be weighed against the long-term gain. This issue is considered in my 1979 paper where the transition path following the elimination of capital income taxation is simulated numerically. It is shown there that convergence to a new steady state is quite rapid, and that at plausible discount rates, the gain far exceeds the transition cost. It is also demonstrated that it is possible to reform taxes in a Pareto-superior way; that is, so that all those alive on or after the day of the changeover are made better off.

IV. Conclusions

The results in this paper suggest that the welfare cost of capital income taxation may have been seriously underestimated. For reasonable parameter values, the annual welfare gain from a shift to consumption taxation is conservatively estimated at 10 percent of *GNP*. This surprising conclusion emerges from an examination of tax effects in the context of a realistic life cycle growth model. The large estimates reported here differ from previous estimates for two main reasons. First, the multiperiod model used here suggests that a very high interest elasticity of savings is likely to obtain for almost any reasonable parameter values. Second, the estimates in this paper incorporate the general equilibrium effects of tax changes. The most important of these is the increase in gross wages which results from the increased capital intensity arising from eliminating capital taxation.

The model used in this study, while more realistic than the conventional two-period formulation, could usefully be extended in several directions. The discussion in this paper ignores the financing of investment. In effect it assumes that all investment is equity financed at the margin. Recently Joseph Stiglitz has suggested that the corporate tax may in reality be a lump sum tax, as corporate investment is completely debt financed at the margin. If this controversial conclusion is correct, it is clear that the analysis here greatly overestimates the welfare cost of capital taxes. The results in this paper underscore the importance of empirical and theoretical research bearing on the effective marginal tax rate on capital income.

This analysis has not considered differential taxation of different types of capital. Alan Auerbach has shown that optimality does not dictate uniform tax rates if overall capital intensity is not at the Golden Rule level. It would be useful to extend the current analysis by examining a corporate tax which falls on only some of the capital used in production.

While these extensions would be valuable, it is unlikely that the basic conclusion of this analysis would be altered. Capital income taxes are likely to appear very undesirable in any sort of realistic life cycle formulation. A question of central importance is the realism of the life cycle hypothesis. While its implication of a high interest elasticity of savings may seem implausible, it is the only framework currently available for evaluating competing tax policies. Examining its realism and/or devising an alternative to it seems a necessary prerequisite to a fuller understanding of the effects of capital taxation.

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Stock Returns, Real Activity, Inflation, and Money

By EUGENE F. FAMA*

There is much evidence that common stock returns and inflation have been negatively related during the post-1953 period. Zvi Body, Jeffrey Jaffe and Gershon Mandelker, Charles Nelson, and my article with G. William Schwert document negative relations between stock returns and both the expected and unexpected components of inflation. These results are puzzling given the previously accepted wisdom that common stock, representing ownership of the income generated by real assets, should be a hedge against inflation.

This paper attempts to explain these anomalous stock return-inflation relations. The data are consistent with the hypothesis that the negative relations between stock returns and inflation are proxying for positive relations between stock returns and real variables which are more fundamental determinants of equity values. The negative stock return-inflation relations are induced by negative relations between inflation and real activity which in turn are explained by a combination of money demand theory and the quantity theory of money. As predicted by the proxy effect hypothesis, the more anomalous of the stock return-inflation relations disappear when both real variables and measures of expected and unexpected inflation are used to explain stock returns.

The first step in the development of this story is to document the negative relations between inflation and real activity. Controlling for the other arguments in the money demand function, especially the nominal money supply, a simple rational expectations version of the quantity theory of money predicts that higher anticipated growth rates of real activity are associated with lower current inflation rates. These predicted negative partial correlations between inflation and real activity are observed consistently in monthly, quarterly, and annual data for the post-1953 period. The negative simple correlation between inflation and real activity, the so-called phenomenon of stagflation, is then traced to the fact that the other important variable in the money demand model for inflation, the nominal quantity of money, does not vary sufficiently with real activity to offset the negative partial correlation between real activity and inflation.

The next step is to study the relations among the real variables presumed to be the fundamental determinants of stock returns. In the theory of finance, the quantity of investments available to firms with expected rates of return in excess of costs of capital is central in the determination of equity values. I study empirically a simple model of the capital expenditures process, similar in spirit to the "flexible accelerator" models summarized by Dale Jorgenson, in which increases in output raise average real rates of return on capital, which in turn induce increased capital expenditures. The tests substantiate that output leads the average real rate of return on capital and that both of these variables lead capital expenditures.

The last set of tests involve relating real common stock returns first to other real variables, then to inflation measures, and finally to combinations of real variables and inflation measures. Real common stock returns are positively related to real variables like capital expenditures, the real rate of return on capital, and output. More interesting, stock returns lead all of the real variables, which suggests that the market makes rational forecasts of the real sector. As in the earlier studies referenced above, stock returns also show strong negative simple corre-

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lations with measures of expected and unexpected inflation. However, in multiple regressions of stock returns on real variables and inflation measures, the most anomalous of the stock return-inflation relations, that between the *ex post* stock return and the *ex ante* expected inflation rate, always disappears. In the annual data, the unexpected component of inflation also has no marginal explanatory power.

In sum, the story proposed is a union of rational expectations models for the monetary and real sectors. The model of the monetary sector says that in setting prices for goods and services, markets for goods make rational assessments of the current nominal money supply and future real activity. The economics of the monetary sector—a combination of money demand theory with an observation on the properties of the money supply process—then implies that the relations between inflation and future rates of growth of real activity are negative. Within the real sector, much of the task of a rational stock market also involves forecasting the values of the real variables that determine equity prices. However, the economics of the real sector implies that the resulting relations between stock returns and anticipated growth rates of real activity are positive. The positive relations between stock returns and real activity that come out of the real sector combine with the negative relations between inflation and real activity that come out of the monetary sector to induce spurious negative relations between stock returns and inflation.

I. Expected and Unexpected Inflation

Two types of models for expected inflation are estimated and compared. One is based on decomposition of interest rates into expected inflation rates and expected real returns. Since the interest rates are observed at the beginning of the time intervals of interest, this approach estimates the *ex ante* expected inflation rates which eventually allow us to document the negative relations between *ex ante* expected stock returns and expected inflation rates. The second approach, based on money demand theory and the quantity theory of money, estimates conditional expected inflation rates as functions of money and real activity growth rates. Since measures of current money and current and future real activity growth rates are major explanatory variables, these conditional expected inflation rates are not *ex ante* measures. However, the money demand-quantity theory models of inflation provide the empirical economic story which explains why the *ex ante* expected inflation rates extracted from interest rates are also strongly related to current and future real activity.

A. *Interest Rates and Expected Inflation Rates*

Following Irving Fisher (1930) the one-period interest rate, TB_{t-1}, observed at the end of period $t-1$ can be broken into an expected real return for period t, ER_{t-1}, and an expected inflation rate, EI_{t-1}:

$$(1) \qquad TB_{t-1} = ER_{t-1} + EI_{t-1}$$

or

$$(2) \qquad EI_{t-1} = -ER_{t-1} + TB_{t-1}$$

The inflation rate for period t, I_t, can then be expressed as

$$(3) \qquad I_t = -ER_{t-1} + TB_{t-1} + \eta_t$$

where η_t is unexpected inflation.

Given a model of bond market equilibrium that renders the expected real return ER_{t-1} observable and a bond market that makes rational assessments of expected inflation, (3) can be used to divide an *ex post* inflation rate into expected and unexpected components. My 1975 article hypothesizes a rational bond market in which the equilibrium expected real return is constant through time. I found that this hypothesis stands up well in data for one- to six-month inflation and interest rates for the 1953–71 period. However, Patrick Hess and James Bicksler, my 1976a article, Charles Nelson and G. William Schwert, and Kenneth Garbade and Paul Wachtel document a small amount of variation in expected real returns

TABLE 1—COMPARISONS OF MONEY DEMAND AND TREASURY BILL RATE MODELS OF INFLATION[a]

Model	Estimated Regression	R^2	$s(\eta)$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_8	ρ_{12}
	Monthly Models								
(1)	$I_t = \underset{(5.78)}{.0016} + \underset{(12.77)}{.058}\, BG_t - \underset{(-6.37)}{.013}\, DPR_t$								
	$- \underset{(-10.41)}{.022}\, DPR_{t+12} + \eta_t$	.50	.0021	.05	.12	−.03	−.02	−.01	.12
(2)	$I_t = \alpha_{t-1} + TB_{t-1} + \eta_t$	.56	.0020	−.01	.07	−.07	−.11	−.05	.12
	Quarterly Models								
(3)	$I_t = \underset{(5.97)}{.0050} + \underset{(12.12)}{.173}\, BG_t - \underset{(-6.81)}{.042}\, DPR_t$								
	$- \underset{(-10.04)}{.067}\, DPR_{t+12} + \eta_t$	.74	.0038	.00	.07	−.07	.13	−.19	.01
(4)	$I_t = \alpha_{t-1} + TB_{t-1} + \eta_t$	.76	.0037	−.11	−.12	.03	.12	−.19	.05
	Annual Models								
(5)	$I_t = \underset{(6.00)}{.0255} + \underset{(3.68)}{.38}\, BG_t + \underset{(3.18)}{.33}\, BG_{t-1}$								
	$- \underset{(-9.02)}{.28}\, DPR_t - \underset{(-6.24)}{.21}\, DPR_{t+1}$								
	$- \underset{(-2.86)}{.10}\, DPR_{t-1} + \eta_t$	.91	.0083	.06	−.08	−.01			
(6)	$I_t = \underset{(-.40)}{-.0014} + \underset{(12.17)}{1.04}\, EITB_{t-1} + \eta_t$	.86	.0106	.10	−.54	−.30			
Summary Statistics for Inflation Rates									
	Monthly		.0030	.55	.57	.51	.50	.48	.46
	Quarterly		.0076	.74	.72	.69	.61	.32	.32
	Annual		.0282	.72	.41	.37			

[a] I_t is the inflation rate for month, quarter, or year t, and TB_{t-1} is the Treasury bill rate observed at the beginning of the month or quarter. BG_t and DPR_t are annual growth rates of the base and industrial production. $EITB_{t-1}$ in regression (6) is the annualized quarterly expected inflation rate from regression (4). R^2 is the coefficient of determination and $s(\eta)$ is the residual standard error, both adjusted for degrees of freedom. The numbers in parentheses below estimated regression coefficients are t-statistics. ρ_τ is the residual autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are zero, the standard errors of the estimated autocorrelations are about .06 for the monthly residuals, about .10 for the quarterly residuals, and about .19 for the annual residuals. Regressions (2), (4), and (6) and the summary statistics for the inflation rates cover the 1953–77 period. Regressions (1), (3), and (5) cover the 1954–76 period.

on bills during the 1953–71 period. Their tests suggest an alternative model in which expected real returns behave like slow moving random walks.

Following up on this evidence, my paper with Michael Gibbons estimates inflation-interest rate regressions

$$(4) \qquad I_t = \alpha_{t-1} + \beta TB_{t-1} + \eta_t$$

with a procedure, developed by Craig Ansley, which presumes that the regression intercept α_{t-1}—the negative of the expected real return ER_{t-1} in (3)—follows a random walk. Leaving detailed discussion of the approach to my paper with Gibbons, suffice it to say that this model succeeds in the sense that, consistent with the hypotheses implied by (3), it yields estimates of β that are close to 1.0 (indeed constraining β to equal 1.0 yields models with smaller residual standard errors than when the regressions are allowed to determine β), and it transforms the highly autocorrelated inflation rates into residuals (unexpected inflation rates) which are indistinguishable from white noise.

The "wandering intercept" regressions estimated from monthly and quarterly inflation and interest rates and with interest rate coefficients constrained to equal 1.0 are shown as models (2) and (4) in Table 1. The inflation rates are calculated from the U.S. Consumer Price Index. The interest rates, taken from the quote sheets of Salomon Brothers and described in more detail in my 1976b book, ch. 6, are those for one- and

three-month Treasury bills observed at the end of the month or quarter preceding the inflation rates with which they are paired. Inflation and interest rates are continuously compounded, and the data are for successive nonoverlapping months or quarters. The fitted values from (2) and (4), i.e., $\alpha_{t-1}+TB_{t-1}$, are henceforth labeled $EITB_{t-1}$ and are my estimates of *ex ante* monthly and quarterly expected inflation rates. The regression residuals η_t are henceforth labeled $UITB_t$ to indicate that they are estimates of the unexpected components of monthly and quarterly inflation.[1]

Obtaining an annual expected inflation rate is less straightforward. One year Treasury bills were not issued regularly prior to 1964, and, in any case, the wandering intercept regression approach is of dubious value with the restricted sample sizes available from post-1953 annual data. My paper with Gibbons argues, however, that shorter period expected inflation rates are close to random walks so that annual expected inflation rates can be obtained by annualizing the beginning of year monthly or quarterly expected inflation rates. An example of this approach is model (6) in Table 1 which shows the regression of the *ex post* annual inflation rate for year t on $EITB_{t-1}$, the annualized, quarterly expected inflation rate. This annual $EITB_{t-1}$ is just four times the quarterly expected inflation rate $EITB_{t-1}=\alpha_{t-1}+TB_{t-1}$ for the first quarter of the year obtained from model (4) of Table 1. Regression (6) indicates that this annualized $EITB_{t-1}$ has good properties as an estimate of the annual *ex ante* expected rate, and we henceforth use it as such. Its estimated regression coefficient is close to 1.0, and it absorbs about 86 percent of the sample variance of the annual inflation rate. The only shortcoming of the regression is a substantial negative second order residual autocorrelation.

B. *Real Activity and Inflation*

I next document the relations between inflation and the measures of current and future real activity which my model presumes are important in the determination of stock market returns. The theoretical basis for the study of inflation-real activity relations is a "rational expectations" combination of money demand theory and a simple version of the quantity theory of money of Fisher (1911). The theory and empirical results are abstracted from my 1980 paper. I present just enough of the theory and evidence to document the inflation-real activity relations of interest.

In brief, for empirical purposes the demand for money function is represented, in differenced form, as

$$(5)\quad \Delta \ln m_t=\Delta \ln M_t-\Delta \ln P_t$$
$$=b_0+b_1\Delta \ln A_t+b_2\Delta \ln R_t+\varepsilon_t$$

where m_t and M_t are the quantities of real and nominal money, P_t is the price level, A_t is a measure of anticipated real activity, R_t is one plus the nominal interest rate, ε_t is a random disturbance, and Δ indicates the difference of the relevant variable.

The theory postulates that $b_2<0.0$, that is, the demand for money at time t is negatively related to the rate of interest set at t since the

[1]Since the coefficient of the interest rate is constrained to equal 1.0, allowing a random walk intercept in an inflation-interest rate regression is equivalent to extracting a random walk from the time-series of the real return $TB_{t-1}-I_t$. That is, α_{t-1} in regression (2) or (4) is the negative of the monthly or quarterly estimated expected real return, and the expected inflation rate, $EITB_{t-1}=\alpha_{t-1}+TB_{t-1}=TB_{t-1}-ER_{t-1}$, is the *ex ante* Treasury bill rate minus the estimated random walk expected real return. Without going into details, the estimation of ER_{t-1} is based on a signal extraction technique which uses the entire sample of real returns, $TB_{t-1}-I_t$. Thus, although the interest rate TB_{t-1} is an *ex ante* variable, $EITB_{t-1}=TB_{t-1}-ER_{t-1}$ is only an estimate of the *ex ante* expected inflation rate since it corrects the interest rate for an estimate of the *ex ante* expected real return which uses all of the information in the sample. However, my paper with Gibbons shows that, although the wandering of expected real returns is statistically reliable, it is small relative to the variation in either expected or unexpected inflation rates. This is consistent with the findings of Hess and Bicksler, my 1976a article, Nelson and Schwert, and Garbade and Wachtel. For present purposes, the implication of these results is that correcting the *ex ante* Treasury bill rate TB_{t-1}, with the estimated expected real return ER_{t-1}, yields an estimate of the *ex ante* expected inflation rate $EITB_{t-1}$ whose variation is largely that of the *ex ante* interest rate, TB_{t-1}.

interest rate is the opportunity cost of holding a unit of money which generates returns in the form of transactions services rather than generalized purchasing power. On the other hand, $b_1 > 0.0$, that is, more real money is demanded at t to accommodate the larger volume of transactions generated by a higher level of real activity anticipated for the near future. I take this assumption that money demand is forward-looking with respect to real activity to be the essence of a rational expectations model of money demand.

To specify the endogenous and exogenous variables in (5), I adopt a simple rational expectations version of the Fisherian quantity theory of money. Thus, real activity is assumed to be determined outside of the monetary sector. Within the monetary sector, the price level is the major endogenous variable while money is exogenous or causal with respect to prices. Finally, without going into the details, which in any case turn out to be empirically irrelevant, my 1980 paper argues that, in a fully rational bond market, the interest rate set at time t is "largely" exogenous with respect to the price level set at t. With real activity, money and the interest rate exogenous, the money demand equation becomes a model for inflation. From (5) we obtain

$$(6)\quad \Delta \ln P_t = -b_0 - b_1 \Delta \ln A_t - b_2 \Delta \ln R_t + b_3 \Delta \ln M_t + \eta_t$$

where $\eta_t = -\varepsilon_t$, $b_3 = 1.0$, and the other parameters are as in (5).

Money demand theory, interpreted from the viewpoint of the quantity theory of money described above, says that, for given values of the interest rate and anticipated real activity, the demand for real money is unaffected by changes in nominal money so the latter must be accommodated by proportionate changes in the price level; that is, b_3 in (6) is equal to 1.0. Likewise, controlling for variation in nominal money and anticipated real activity, a negative relation between real money demanded and the interest rate ($b_2 < 0.0$ in (5)) implies a positive relation in (6) between the inflation rate and the change in the interest rate. Finally, and most interesting for our purposes, money demand theory says that a fall in anticipated real activity lowers the demand for real money, which, given nominal money and the rate of interest, is accommodated by a rise in the price level. In other words, controlling for variation in other variables, a positive relation between money and anticipated real activity in the money demand equation ($b_1 > 0$ in (5)) implies a negative relation between the inflation rate and the anticipated growth rate of real activity in (6). The major hypothesis of this paper is that this negative relation between inflation and real activity, with real activity assumed to cause inflation, is the key to the spurious negative relations between stock returns and inflation observed during the post-1953 period.

Estimates of (6) for monthly, quarterly, and annual inflation rates are shown as regressions (1), (3) and (5) in Table 1. In the annual regression (5), the real activity measures are current, future, and past annual growth rates of industrial production, DPR_t, DPR_{t+1}, and DPR_{t-1}. Money growth is measured by base (currency plus reserves held against deposits) growth rates BG_t, since these always have more power in explaining inflation than other monetary measures like demand deposit growth rates or $M1$ (currency plus demand deposits) growth rates—a finding discussed and interpreted at length in my 1980 paper, where the data are also discussed in detail. In the annual regression (5), both the current base growth rate BG_t and the lagged growth rate BG_{t-1} are included as explanatory variables. None of the inflation regressions, (1), (3), and (5) of Table 1 contain the change in the interest rate as an explanatory variable, reflecting the finding in my 1980 paper that interest changes never have reliable marginal explanatory power. This corresponds, of course, to the general finding in the money demand literature that the interest rate is the weakest variable in empirical money demand equations.

The explanatory variables in the monthly and quarterly regressions (1) and (3) are annual growth rates of the base and industrial production. BG_t and DPR_t are the annual growth rates of the base and industrial production for the year ending with month or

quarter t, and DPR_{t+12} is the growth rate of industrial production for the year following month or quarter t. Without going into the details of the discussion provided in my 1980 paper, the choice of annual growth rates as explanatory variables is a response to problems that arise from the fact that short-term real activity and money growth rates are highly seasonal whereas inflation rates are not. Annual growth rates of the base and industrial production are, in effect, deseasonalized variables that seem to produce good descriptions of short-term inflation.

The inflation regressions (1), (3), and (5) are statistically well specified in the sense that they absorb substantial fractions of the variation in monthly, quarterly, and annual inflation rates, and they transform the highly autocorrelated inflation rates into well-behaved residuals. As predicted by money demand theory, all estimated coefficients of real activity growth rates are reliably negative, while the estimated coefficients of base growth rates are reliably positive. The coefficients in the monthly and quarterly regressions (1) and (3) are much smaller than those in the annual regression (5). This is due to the fact that the monthly and quarterly inflation rates are explained in terms of annual growth rates of the base and industrial production. In the monthly and quarterly regressions, the estimated regression coefficients must be multiplied by twelve and four to estimate the elasticities of the monthly and quarterly inflation rates with respect to the average monthly and quarterly growth rates of money and real activity. When this is done, the elasticities from the monthly, quarterly, and annual regressions are quite similar.

There are several respects in which the results from the estimated money demand inflation regressions are countertheoretical. My 1980 paper explains that, in a fully rational market for goods, only the contemporaneous money growth rate should appear in the inflation regression, and its coefficient should be 1.0. The estimated annual regression (5), for example, also contains a lagged base growth rate, and the estimated combined elasticity of inflation, I_t, with respect to BG_t and BG_{t-1} is only .71. My 1980 paper explains these countertheoretical results in part in terms of the effects of errors in the measured values of the base growth rates.

Another important shortcoming of the estimated money demand inflation regression is the use of actual growth rates of real activity as explanatory variables instead of the anticipated growth rates called for by a forward-looking rational expectations version of the money demand model. My 1980 paper argues that it is best to regard the past and future growth rates of output that appear as explanatory variables in the inflation regressions as together proxying for the relations between inflation and anticipations of real activity. The implied measurement error problems prevent us from putting much emphasis on the specific estimated values of the real activity coefficients. However, for our purposes, the important result is the uniform evidence that the inflation-real activity relations have the negative sign which is the key to the story I later propose for the negative relations between stock returns and inflation.

C. *Stagflation*

The negative relations between inflation and real activity predicted by the money demand-quantity theory model and observed consistently in the regressions are negative partial correlations. However, the cross correlations in Table 2 show that measures of current and future real activity have negative simple correlations both with the annual inflation rate I_t observed for year t and with the estimated *ex ante* annual expected inflation rate $EITB_{t-1}$ extracted from the interest rate observed at the beginning of the year.

Table 2 also provides evidence on why the negative partial correlations between inflation and real activity predicted by the money demand model turn into the post-1953 phenomenon of stagflation, that is, negative simple correlations between inflation and real activity. In the money demand inflation regressions (1), (3), and (5) of Table 1, the important explanatory variable, in addition to real activity growth rates, is the growth rate of the monetary base which always shows strong positive relations with inflation. In

TABLE 2—CROSS CORRELATIONS: 1953–77[a]

X_t	$Y_{t+\tau}$	τ −1	0	+1
I_t	$DRGNP_{t+\tau}$	.14	−.26	−.45
	$DPR_{t+\tau}$	.09	−.38	−.33
	$DCX/NS_{t+\tau}$	−.13	−.34	−.36
	$DROC_{t+\tau}$	−.05	−.40	−.48
$EITB_{t-1}$	$DRGNP_{t+\tau}$	−.04	−.38	−.26
	$DPR_{t+\tau}$	−.09	−.40	−.14
	$DCX/NS_{t+\tau}$	−.13	−.34	−.36
	$DROC_{t+\tau}$	−.22	−.51	−.34
BG_t	$DRGNP_{t+\tau}$	.03	.05	.17
	$DPR_{t+\tau}$	−.04	.20	−.03
	$DCX/NS_{t+\tau}$	−.06	−.14	.11
	$DROC_{t+\tau}$	−.10	−.07	.01

[a]The table shows cross correlations between the value of the variable X for year t and the value of the variable Y for year $t+\tau$. I_t is the inflation rate for year t, BG_t is the base growth rate, and $EITB_{t-1}$ is the expected inflation rate for year t from the Treasury bill rate model (6) of Table 1. DPR_t is the rate of growth of industrial production for year t, and $DRGNP_t$ is the rate of growth of real GNP. The variable DCX/NS_t is the change in the rate of capital expenditures of nonfinancial corporations for year t, and $DROC_t$ is the change in the after tax average real rate of return on their capital stock. See fn. 2 for more precise definitions of DCX/NS_t and $DROC_t$.

terms of these regressions, transforming the observed negative partial correlations between inflation and real activity into positive simple correlations would require strong positive correlations between the base and real activity growth rates. Table 2 indicates, however, that the actual correlations are small and not even systematically positive.

Explanation of the absence of positive simple relations between money supply and real activity growth rates during the post-1953 period is an interesting topic for future research. This is especially so since the monetary measure used, the growth rate of the base, is the one most under the control of the monetary authorities.

II. The Primrose Path

At this point it is well to outline where we have been and where we must go to complete the story. The results above establish that inflation for month, quarter, or year t is related to the growth rate of real activity for the following year. Taking the simple quantity theory viewpoint that real activity is exogenous with respect to inflation, these results imply that markets for goods make forecasts of real activity which are used in setting current prices of goods. The hypothesis studied next is that forecasts of real activity are also the important determinants of common stock returns. The final step is then to test the key hypothesis that the negative stock return-inflation relations of the post-1953 period are induced by the combination of positive stock return-real activity relations and negative real activity-inflation relations.

III. The Capital Expenditures Process and Common Stock Returns

In the theory of finance, the process generating capital investments with expected rates of return in excess of costs of capital, equivalently, investment projects whose market values exceed costs of acquisition, is central in the determination of stock returns. Estimation of a full-blown investment model would be a formidable project. The more limited goal here is to study the relations proposed by a bare-bones model of investments in order to identify real variables which are potentially important in the determination of stock returns. These real variables can then be put against measures of expected and unexpected inflation in stock return regressions.

A. *Capital Expenditures and Inflation*

The simple model proposed for the capital expenditures process captures the spirit of the "flexible accelerator" models summarized by Jorgenson. In brief, an increase in the general level of real activity puts pressure on the existing capital stock, raising the average return on the existing stock and thus inducing increased capital expenditures.

Estimates of this proposed chain of relations on annual data are shown in Table 3. The measure of general real activity used is the rate of change of industrial production, DPR_t. The rate of change of real GNP yields similar results. The dependent variables in the regressions are the change in the rate of

capital expenditures of nonfinancial corporations, DCX/NS_t, and the change in the after tax average real rate of return on their capital stock, $DROC_t$.[2] I work with the differences of the variables because of evidence from preliminary regressions that the high autocorrelations of the levels (Table 4) generally show up in regression residuals. The differences of the variables are less autocorrelated and residual autocorrelation does not seem to be a problem in regressions based on the differences. Moreover, in a rational expectations world, one would presume (and preliminary tests confirmed) that stock market returns respond to new information from the investment process. The less autocorrelated differences DCX/NS_t and $DROC_t$, along with DPR_t, come closer to representing new information about the variables in the capital expenditures process than the highly autocorrelated levels CX/NS_t and ROC_t.

The results in Table 3 are consistent with the simple description of the investment process proposed above. Regressions (1) to (3) show that capital expenditures are led by both the average real rate of return on capital and industrial production, while the average real rate of return on capital is led by industrial production. Other preliminary tests always yielded a pattern of relations similar to that observed in regressions (1) to (5). Industrial production is always the leading variable in the investment process, and capital investment is the lagging variable.

In a world of rational expectations, desired capital expenditures adjust to anticipated changes in future real activity and the average real rate of return on capital. As a consequence, DCX/NS_t could lead DPR_t and $DROC_t$. The fact that DCX/NS_t is a lagging variable suggests one of the common models in which there are costs in adjusting the capital stock rapidly to new equilibrium levels. See, for example, the summary of these models given by Jorgenson.

Regressions (6) and (7) in Table 3 describe DCX/NS_t and $DROC_t$ in terms of measures of expected and unexpected inflation as well as the real variables that appear in regressions (3) and (5). The measure of the annual *ex ante* expected inflation rate is $EITB_{t-1}$ from the annual inflation-interest rate regression (6) of Table 1 and the unexpected inflation rate $UITB_t$ is just the difference between the *ex post* inflation rate for year t and $EITB_{t-1}$. Table 2 shows that there are negative simple correlations between DCX/NS_t or $DROC_t$ and current and past inflation and expected inflation rates. However, regressions (6) and (7) of Table 3 show that although the intercorrelation of the inflation measures and the real variables leads to some attenuation of t-statistics, the real variables nevertheless dominate the inflation measures, and the latter have no marginal power in the description of DCX/NS_t and $DROC_t$. Thus, measures of expected and unexpected

[2] CX/NS_t is the ratio of capital expenditures (equipment, structures, and residential capital, although the latter is always a small fraction of the total) by nonfinancial corporations during year t to a current cost measure of their net capital stock at the end of the year. The latter is net of straight-line depreciation at assumed asset lives which are 85 percent of those used in the guidelines provided by the U.S. Treasury Internal Revenue Service Bulletin F. The data are updated and revised versions of those in *Fixed Nonresidential Business and Residential Capital in the United States, 1925-75*, provided by John C. Musgrave of the BEA.

ROC_t is an estimate of the average real rate of return on capital for the nonfinancial corporate sector during year t. The denominator is the end of year net capital stock in the denominator of CX/NS_t, plus the BEA's estimate of the current value of end of year inventories. The numerator is the before-tax cash flow to nonfinancial corporations (the sum of (1) profits before taxes, (2) depreciation taken for tax purposes, and (3) monetary net interest paid), less the BEA's estimate of replacement cost depreciation (called "capital consumption allowances with capital consumption adjustments" in the National Income and Product Accounts), and less federal, state, and local corporate profits tax liabilities. Since the items in the denominator of ROC_t are estimated in terms of prices for the same year as those in the numerator, the resulting ratio is an average real rate of return on capital after taxes and after an estimate of the current service value of the capital stock, that is, net of a replacement cost measure of depreciation. It is, however, an income or accounting rate of return in that real capital gains or losses on the capital stock are not included. The data for the numerator of ROC_t are from *The National Income and Products Accounts of the United States, 1929-74; Statistical Tables*, as updated in the July 1977 and July 1978 issues of the *Survey of Current Business*. Monetary interest figures are from Table 8.2 of these publications. Profits before taxes, profits tax liability, and capital consumption allowances are those for all corporations in Tables 8.5 and 8.7, less the corresponding numbers for the finance, insurance, and real estate sector in Tables 6.19, 6.20, and 6.24.

Finally, DCX/NS_t and $DROC_t$ are the first differences of CX/NS_t and ROC_t.

TABLE 3—CAPITAL EXPENDITURES AND REAL RATE OF RETURN ON CAPITAL REGRESSIONS: 1954–77[a]

Model	Estimated Regression	R^2	$s(\varepsilon)$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5
(1)	$DCX/NS_t = \underset{(-.86)}{-.0011} + \underset{(3.62)}{.56}\, DROC_t$							
	$+ \underset{(2.55)}{.39}\, DROC_{t-1} + \varepsilon_t$	.47	.00648	−.05	−.48	.04	.19	−.00
(2)	$DCX/NS_t = \underset{(-4.04)}{-.0066} + \underset{(2.33)}{.048}\, DPR_t$							
	$+ \underset{(5.67)}{.112}\, DPR_{t-1} + \varepsilon_t$	.59	.00569	−.02	−.29	.09	.03	−.00
(3)	$DROC_t = \underset{(-2.73)}{-.0053} + \underset{(3.94)}{.096}\, DPR_t$							
	$+ \underset{(2.30)}{.053}\, DPR_{t-1} + \varepsilon_t$	.43	.00671	.00	.16	−.01	−.29	−.08
(4)	$DCX/NS_t = \underset{(-2.35)}{-.0043} + \underset{(2.17)}{.38}\, DROC_t$							
	$+ \underset{(.66)}{.10}\, DROC_{t-1} + \underset{(.43)}{.011}\, DPR_t$							
	$+ \underset{(3.37)}{.083}\, DPR_{t-1} + \varepsilon_t$	.64	.00533	−.07	−.53	−.01	.27	.03
(5)	$DCX/NS_t = \underset{(-3.25)}{-.0040} + \underset{(3.33)}{.42}\, DROC_t$							
	$+ \underset{(4.72)}{.088}\, DPR_{t-1} + \varepsilon_t$	.66	.00516	−.06	−.53	−.01	.31	.04
(6)	$DCX/NS_t = \underset{(-1.76)}{-.0042} + \underset{(1.37)}{.26}\, DROC_t$							
	$+ \underset{(3.52)}{.127}\, DPR_{t-1} - \underset{(-1.08)}{.25}\, EITB_{t-1}$							
	$+ \underset{(.08)}{.01}\, UITB_t + \underset{(1.08)}{.23}\, EITB_{t-2}$							
	$+ \underset{(.40)}{.09}\, UITB_{t-1} + \varepsilon_t$	.64	.00536	−.10	−.61	.01	.37	.11
(7)	$DROC_t = \underset{(.07)}{.0003} + \underset{(1.04)}{.040}\, DPR_t$							
	$+ \underset{(2.07)}{.084}\, DPR_{t-1} - \underset{(-1.67)}{.49}\, EITB_{t-1}$							
	$+ \underset{(1.14)}{.21}\, UITB_t + \underset{(1.43)}{.39}\, EITB_{t-2}$							
	$+ \underset{(.76)}{.21}\, UITB_{t-1} + \varepsilon_t$	.43	.00671	.04	.05	−.22	−.22	−.07

[a] DCX/NS_t is the change in the rate of capital expenditures of nonfinancial corporations from year $t-1$ to year t, and $DROC_t$ is the change in the average real rate of return on their capital stock. DPR_t is the rate of change of industrial production. $EITB_{t-1}$ and $UITB_t$ are expected and unexpected inflation rates for year t from the annual Treasury bill rate model. R^2 is the coefficient of determination and $s(\varepsilon)$ is the residual standard error, both adjusted for degrees of freedom. The numbers in parentheses below estimated regression coefficients are t-statistics. ρ_τ is the residual autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are zero, the standard errors of the residual autocorrelations are approximately .19.

inflation do not seem to be direct determinants of either capital expenditures or the average real rate of return on capital.

It is appropriate to recall, however, that the money demand models of inflation in Table 1 document strong relations between inflation and industrial production, and the latter is the leading variable in the capital expenditures process. Moreover, there are many papers in the macroeconomic literature, for example, those by Robert Mundell, James Tobin, Milton Friedman (1977), Robert Lucas, and Robert Barro, which propose lines of causation from inflation (and money) to real activity. However, all the popular stories are variants of the "Phillips curve" in which the proposed inflation-output relations are positive. The negative

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TABLE 4—SUMMARY STATISTICS FOR ANNUAL VARIABLES: 1953–77[a]

Variable (x)	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	$\bar{x}$	$s(x)$
I_t	.72	.41	.37	.36	.28	.03377	.02823
BG_t	.73	.67	.59	.46	.33	.04598	.03055
CX/NS_t	.71	.36	.22	.07	−.14	.12720	.01177
ROC_t	.75	.44	.26	.09	−.09	.07035	.01323
DCX/NS_t	.03	−.36	.09	.16	−.13	−.00033	.00883
$DROC_t$	.14	−.11	−.12	−.03	−.25	.00059	.00870
$DRGNP_t$	−.03	−.24	−.07	.26	−.06	.03201	.02512
DPR_t	−.09	−.42	.13	.20	−.15	.03692	.05933
RS_t	−.04	−.35	.10	.34	.06	.05562	.19791

[a] I_t is the inflation rate for year t; $DRGNP_t$ and DPR_t are the rates of growth of industrial production and real GNP for year t; BG_t is the rate of growth of the monetary base; RS_t is the real rate of return on common stocks; ROC_t is the after-tax average real rate of return on the capital stock of nonfinancial corporations for year t and CX/NS_t is the ratio of their capital expenditures to their net capital stock; $DROC_t$ and DCX/NS_t are the differences of ROC_t and CX/NS_t; $\bar{x}$ and $s(\bar{x})$ are the mean and standard deviation of the variable and ρ_t is its autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are equal to zero, the standard errors of the estimated autocorrelations are about .19.

relations between inflation and real activity documented in Tables 1 and 2 seem more consistent with a simple money demand-quantity theory world in which anticipated increases in real activity cause increases in real money demanded which, empirically, are not satisfied by nominal money growth and so must be accommodated by opposite movements in inflation.

Finally, since ROC_t is a measure of the after-tax average real rate of return on the capital stock of nonfinancial corporations, the absence of any marginal effect of expected or unexpected inflation in the $DROC_t$ regression (7) is evidence against the popular hypothesis that negative stock return-inflation relations are the consequence of overtaxation of corporate profits during inflation. (See, for example, the paper by John Lintner.) To check that the regressions are not masking tax effects that might occur during the last few high inflation years, the residuals from regression (3) of $DROC_t$ on DPR_t and DPR_{t-1} were examined. The tax effects hypothesis would predict negative residuals during the high inflation years 1971–74, but the residuals are in fact positive.[3]

[3]An earlier version of this paper, which included an explicit analysis of income taxes paid by nonfinancial corporations, concluded that the average rate of taxation of pretax cash flows declined during most of the post-1953 period and showed no tendency to increase during the later high inflation years. The offsets to the higher taxation of corporate profits during inflation that follow from historical cost expensing of depreciation and inventories seemed to come from (i) interest deductions that vary directly with inflation when interest rates reflect assessments of expected inflation, (ii) liberalized tax rules with respect to asset lives and accelerated depreciation, and (iii) investment tax credits and other tax rules with respect to additional first-year depreciation of assets. I intend to present an expanded version of these results in a separate paper. See also the paper by Nicholas Gonedes.

B. *Stock Returns and the Real Variables*

Table 5 documents strong positive relations between a measure of annual real common stock returns, RS_t, and the real variables from the capital investment process.[4] For example, next year's change in the capital expenditures ratio, DCX/NS_{t+1}, alone explains 54 percent of the sample variance of the current real stock market return, and next year's change in the real rate of return on capital, $DROC_{t+1}$, explains 40 percent of the sample variance of RS_t. Preliminary tests showed that the stock return is never led by any of the real variables, and as indicated by

[4]The real stock return RS_t is the annual continuously compounded nominal return on a value weighted portfolio of all New York Stock Exchange common stocks less the annual continuously compounded inflation rate calculated from the U.S. Consumer Price Index. The nominal stock return is from the Center for Research in Security Prices of the University of Chicago. The monthly and quarterly versions of RS_t used in later sections are defined similarly.

TABLE 5—REGRESSIONS OF ANNUAL REAL STOCK RETURNS ON CURRENT AND FUTURE MEASURES OF REAL ACTIVITY: 1954–76[a]

Model	Estimated Regression	R^2	$s(\varepsilon)$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5
(1)	$RS_t = \underset{(2.42)}{.070} + \underset{(5.14)}{16.94}\, DCX/NS_{t+1} + \varepsilon_t$	.54	.138	.11	−.07	.13	.06	−.19
(2)	$RS_t = \underset{(1.77)}{.058} + \underset{(3.94)}{14.56}\, DROC_{t+1} + \varepsilon_t$	.40	.157	.27	−.10	−.05	.08	−.22
(3)	$RS_t = \underset{(-2.12)}{-.088} + \underset{(4.44)}{2.22}\, DPR_t + \underset{(3.19)}{1.59}\, DPR_{t+1} + \varepsilon_t$	.54	.138	.14	.28	.06	−.01	−.02
(4)	$RS_t = \underset{(-4.10)}{-.169} + \underset{(6.96)}{6.97}\, DRGNP_{t+1} + \varepsilon_t$	.68	.114	.41	.23	.09	.16	−.07
(5)	$RS_t = \underset{(-1.99)}{-.110} + \underset{(3.58)}{5.26}\, DRGNP_{t+1} + \underset{(1.55)}{6.18}\, DCX/NS_{t+1} + \varepsilon_t$	.70	.111	.46	.36	.13	−.01	−.26

[a] RS_t is the real stock return for year t; DCX/NS_t is the change in the rate of capital expenditures of nonfinancial corporations from year $t-1$ to year t, and $DROC_t$ is the change in the average real rate of return on their capital stock; DPR_t and $DRGNP_t$ are the rates of change of industrial production and real GNP; R^2 is the coefficient of determination and $s(\varepsilon)$ is the residual standard error, both adjusted for degrees of freedom. The numbers in parentheses below estimated regression coefficients are t-statistics. ρ_τ is the residual autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are zero, the standard errors of the estimated autocorrelations are about .19.

the choice of explanatory variables in regressions (1) to (4), the growth rate of industrial production is the only real variable that shows a strong contemporaneous relation with the stock return. Since DPR_t is also the overall leading variable in the capital expenditures process, the evidence in Table 5 suggests a "rational expectations" or "efficient markets" view in which the stock market is concerned with the capital investment process and uses the earliest information from the process to forecast its evolution.

Regression (4) indicates that next year's rate of change in real GNP, $DRGNP_{t+1}$, explains slightly more of the variation of the current stock return than the future change in the capital expenditures ratio DCX/NS_{t+1}, and this impression is reinforced in regression (5). However, the attenuation of regression coefficients and t-statistics observed in regression (5) when compared to regressions (1) and (4) suggests that $DRGNP_{t+1}$ and DCX/NS_{t+1} contain similar information about the real stock market return. Additional tests indicated that DCX/NS_{t+1} is the only real variable with even a bit of marginal explanatory power in annual stock return regressions that also include $DRGNP_{t+1}$ as an explanatory variable.

The fact that $DRGNP_{t+1}$ captures most of the information in the other real variables is fortuitous since it allows a simplified strategy for presentation of the tests that follow in which we try to explain monthly, quarterly, and annual real stock returns in terms of real activity, money growth, and measures of expected and unexpected inflation. The real variables used are current and future rates of change of output (industrial production and real GNP). This choice is dictated by data availability for the monthly and quarterly tests. A wider range of real variables, for example, capital expenditures and the real rate of return on capital, were tried in preliminary annual tests with results similar to those shown below in which rates of change of real GNP are used to summarize annual real activity.

Finally, a shortcoming of the real stock return regressions, both those in Table 5 and those presented below, is the use of actual growth rates of future real activity instead of anticipated growth rates. Under the presumption that the anticipations of future real activity on which the current stock return is based are fully rational, what we would like are the conditional expected values of future real activity measures from the "true" structural model of the business cycle. This "holy grail" of macroeconomics is more than a bit beyond the scope of this paper. Moreover, given the evidence in Table 4 that the annual growth rates of the various measures of real activity are close to white noise, time-series

models for the expected future growth rates are not viable alternatives.

Since the point has been raised by many readers, it is also well to note that if we had a candidate structural model for the real sector, we could test the proposition of this section that the current real stock return is caused by anticipations of future real activity while future real activity is not caused by the current stock return—in short, that real activity is exogenous with respect to the stock return. We could also test the proposition of the money demand-quantity theory model that real activity is exogenous with respect to inflation. In the framework suggested by Christopher Sims and John Geweke, the implication of the exogeneity proposition is that expected future rates of change of real activity are a function only of current and past values of real variables which are not caused by either stock returns or inflation. Thus, when rates of change of future real activity are regressed on current and past values of these exogenous real variables and on current and past inflation rates or stock returns, the latter should have no marginal explanatory power.

Unfortunately, the model is likely to flunk these exogeneity tests when in fact it is true and when markets are characterized by rational expectations. Since we are not likely to find the exact form of the true structural model or all of the exogenous variables which are relevant in explaining the growth rates of real activity, current and past inflation rates or stock returns set by rational markets are likely to have marginal explanatory power in the Sims-Geweke tests; that is, the tests are likely to lead to the false conclusion that future real activity is caused by past inflation rates and stock returns.

IV. Stock Returns, Real Activity, and Expected and Unexpected Inflation

The results presented above establish the two major separate pieces of our story. Measures of inflation and expected inflation are strongly related to future real activity (Tables 1 and 2), and real stock returns are also strongly related to future real activity (Table 5). It is time to deliver the punchline, that is, to test whether the stock return-inflation relations observed during the post-1953 period proxy for more fundamental relations between stock returns and real activity.

The tests—three sets of similar regressions on monthly, quarterly and annual stock returns—are in Table 6. The first model in each section is the estimated regression of the real stock return (monthly, quarterly, or annual) on the expected and unexpected inflation rates, $EITB_{t-1}$ and $UITB_t$, from the Treasury bill rate models of inflation (regressions (2), (4) and (6) of Table 1). The second regression in each section is the regression of the real stock return on the conditional expected and unexpected inflation rates, $EIMD_t$ and $UIMD_t$, from the money demand inflation models. $EIMD_t$ is the fitted value from

TABLE 6—MONTHLY, QUARTERLY AND ANNUAL REAL STOCK RETURN REGRESSIONS: 1954–76[a]

Model	Estimated Regression	R^2	$s(\varepsilon)$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_8	ρ_{12}
($M1$)	$RS_t = \underset{(4.70)}{.018} - \underset{(-4.16)}{4.58}\, EITB_{t-1} - \underset{(-2.93)}{3.53}\, UITB_t + \varepsilon_t$	.084	.0392	.04	−.03	.02	.09	−.03	.08
($M2$)	$RS_t = \underset{(5.00)}{.020} - \underset{(-4.52)}{5.03}\, EIMD_t - \underset{(-2.80)}{3.15}\, UIMD_t + \varepsilon_t$	.087	.0391	.04	−.04	.02	.09	−.03	.08
($M3$)	$RS_t = \underset{(1.20)}{.006} - \underset{(-.51)}{.018}\, DPR_t + \underset{(5.30)}{.20}\, DPR_{t+12} - \underset{(-2.18)}{.18}\, BG_t - \underset{(-2.87)}{3.15}\, UIMD_t + \varepsilon_t$	.131	.0382	−.02	−.09	−.03	.05	−.04	.10

Model	Estimated Regression	R^2	$s(\varepsilon)$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_8	ρ_{12}
$(M4)$	$RS_t = \underset{(.64)}{.004} + \underset{(3.61)}{.23}\, DPR_{t+12} - \underset{(-1.49)}{.27}\, BG_t + \underset{(.51)}{1.45}\, EIMD_t - \underset{(-2.87)}{3.15}\, UIMD_t + \varepsilon_t$	.131	.0382	−.02	−.09	−.03	.05	−.04	.10
$(M5)$	$RS_t = \underset{(1.13)}{.006} + \underset{(3.80)}{.19}\, DPR_{t+12} - \underset{(-1.17)}{.18}\, BG_t - \underset{(-.11)}{.24}\, EITB_{t-1} - \underset{(-2.75)}{3.24}\, UITB_t + \varepsilon_t$	.128	.0383	−.02	−.10	−.03	.05	−.04	.10
$(M6)$	$RS_t = \underset{(1.05)}{.005} + \underset{(3.79)}{.16}\, DPR_{t+12} - \underset{(-1.95)}{2.38}\, EITB_{t-1} - \underset{(-2.71)}{3.20}\, UITB_t + \varepsilon_t$	.127	.0383	−.01	−.09	−.02	.05	−.03	.10
$(M7)$	$RS_t = \underset{(1.19)}{.006} + \underset{(5.32)}{.20}\, DPR_{t+12} - \underset{(-2.27)}{.19}\, BG_t - \underset{(-2.76)}{3.25}\, UITB_t + \varepsilon_t$	.131	.0382	−.02	−.10	−.03	.05	−.04	.10
$(Q1)$	$RS_t = \underset{(3.80)}{.050} - \underset{(-3.26)}{4.08}\, EITB_{t-1} - \underset{(-3.94)}{8.90}\, UITB_t + \varepsilon_t$	.220	.0761	−.02	−.13	−.08	−.03	−.11	.10
$(Q2)$	$RS_t = \underset{(4.37)}{.058} - \underset{(-3.95)}{4.97}\, EIMD_t - \underset{(-2.86)}{6.16}\, UIMD_t + \varepsilon_t$	.193	.0774	.02	−.14	−.03	.02	−.09	.11
$(Q3)$	$RS_t = \underset{(.58)}{.009} - \underset{(-.14)}{.02}\, DPR_t + \underset{(5.40)}{.66}\, DPR_{t+12} - \underset{(-1.67)}{.45}\, BG_t - \underset{(-3.08)}{6.16}\, UIMD_t + \varepsilon_t$	.306	.0718	−.09	−.19	−.04	.07	−.05	.08
$(Q4)$	$RS_t = \underset{(.41)}{.007} + \underset{(3.57)}{.69}\, DPR_{t+12} - \underset{(-.98)}{.51}\, BG_t + \underset{(.14)}{.38}\, EIMD_t - \underset{(-3.08)}{6.16}\, UIMD_t + \varepsilon_t$	.306	.0718	−.09	−.19	−.04	.07	−.05	.08
$(Q5)$	$RS_t = \underset{(.79)}{.013} + \underset{(3.60)}{.56}\, DPR_{t+12} - \underset{(-.82)}{.37}\, BG_t - \underset{(-.22)}{.50}\, EITB_{t-1} - \underset{(-3.28)}{7.13}\, UITB_t + \varepsilon_t$	.315	.0713	−.11	−.22	−.11	−.00	−.06	.12
$(Q6)$	$RS_t = \underset{(.71)}{.012} + \underset{(3.70)}{.50}\, DPR_{t+12} - \underset{(-1.51)}{1.97}\, EITB_{t-1} - \underset{(-3.34)}{7.23}\, UITB_t + \varepsilon_t$	.317	.0712	−.10	−.20	−.08	.02	−.06	.12

(Continued)

TABLE 6—*Continued*

Model	Estimated Regression	R^2	$s(\varepsilon)$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_8	ρ_{12}
(Q7)	$RS_t = \underset{(.77)}{.012} + \underset{(4.84)}{.58}\, DPR_{t+12} - \underset{(-1.71)}{.45}\, BG_t - \underset{(-3.29)}{7.10}\, UITB_t + \varepsilon_t$	.322	.0709	−.11	−.22	−.11	−.01	−.06	.12
(A1)	$RS_t = \underset{(3.72)}{.183} - \underset{(-3.16)}{3.65}\, EITB_{t-1} - \underset{(-4.01)}{11.25}\, UITB_t + \varepsilon_t$	.54	.138	−.22	−.03	.03	.11		
(A2)	$RS_t = \underset{(4.41)}{.233} - \underset{(-4.03)}{4.98}\, EIMD_t - \underset{(-.66)}{3.03}\, UIMD_t + \varepsilon_t$	.40	.157	−.10	−.16	.05	.19		
(A3)	$RS_t = \underset{(-1.55)}{-.088} - \underset{(-.37)}{.32}\, DRGNP_t + \underset{(7.70)}{7.35}\, DRGNP_{t+1} - \underset{(-2.41)}{1.84}\, BG_t + \underset{(.80)}{2.53}\, UIMD_t + \varepsilon_t$	.73	.105	.06	.05	−.07	.13		
(A4)	$RS_t = \underset{(-1.29)}{-.097} + \underset{(4.24)}{7.35}\, DRGNP_{t+1} - \underset{(-1.24)}{1.83}\, BG_t - \underset{(-.01)}{.02}\, EIMD_t + \underset{(.76)}{2.57}\, UIMD_t + \varepsilon_t$	.73	.106	.10	.10	−.06	.09		
(A5)	$RS_t = \underset{(-1.25)}{-.109} + \underset{(3.25)}{7.67}\, DRGNP_{t+1} - \underset{(-1.32)}{2.18}\, BG_t + \underset{(.23)}{.48}\, EITB_{t-1} + \underset{(.20)}{.89}\, UITB_t + \varepsilon_t$	.72	.108	.10	.05	−.02	.09		
(A6)	$RS_t = \underset{(-.62)}{-.047} + \underset{(3.57)}{5.20}\, DRGNP_{t+1} - \underset{(-1.84)}{1.91}\, EITB_{t-1} - \underset{(-1.12)}{3.50}\, UITB_t + \varepsilon_t$	.71	.110	.24	.15	−.00	.07		
(A7)	$RS_t = \underset{(-1.78)}{-.093} + \underset{(5.67)}{7.22}\, DRGNP_{t+1} - \underset{(-2.34)}{1.84}\, BG_t + \underset{(.04)}{.11}\, UITB_t + \varepsilon_t$	.73	.105	.12	.07	−.01	.08		
(A8)	$RS_t = \underset{(-1.92)}{-.092} + \underset{(7.97)}{7.18}\, DRGNP_{t+1} - \underset{(-2.49)}{1.83}\, BG_t + \varepsilon_t$	.75	.102	.12	.07	−.01	.09		
(A9)	$RS_t = \underset{(-4.10)}{-.169} + \underset{(6.96)}{6.97}\, DRGNP_{t+1} + \varepsilon_t$	.68	.114	.41	.23	.09	.16		

[a] RS_t is the monthly, quarterly, or annual real stock market return. $EITB_{t-1}$ and $UITB_t$ are the monthly, quarterly or annual expected and unexpected inflation rates from the Treasury bill rate models of inflation, while $EIMD_t$ and $UIMD_t$ are conditional expected and unexpected inflation rates from the money demand models. BG_t, DPR_t, and $DRGNP_t$ are annual growth rates of the monetary base, industrial production and real *GNP* for year t (in the annual stock return regressions) or for the year ending in month or quarter t (in the monthly and quarterly stock return regressions). R^2 is the coefficient of determination and $s(\varepsilon)$ is the residual standard error, both adjusted for degrees of freedom. The numbers in parentheses below estimated regression coefficients are t-statistics. ρ_τ is the residual autocorrelation at lag τ. Under the hypothesis that the true autocorrelations are zero, the standard errors of the estimated autocorrelations are approximately .06, .10, and .19 in the monthly, quarterly and annual data.

the inflation regression (1), (3), or (5) of Table 1, and $UIMD_t$ is the regression residual. The remaining regressions in each section are concerned with how measures of real activity and money growth compete with the measures of expected and unexpected inflation in the description of real common stock returns.

A. *Stock Returns and Inflation*

The first two regressions of each section of Table 6 document statistically reliable negative relations between real stock returns and measures of expected and unexpected inflation similar to those reported by Bodie, Jaffe and Mandelker, Nelson, and Schwert and myself. However, even these results contain suggestive evidence that the stock market is concerned with inflation for the information it contains about future real activity.

Thus, in setting the end-of-period prices of goods built into the *ex post* inflation rate I_t for month, quarter, or year t, markets for goods have the benefit of increasing amounts (specifically, a month, quarter, or year) of information about future real activity which was not available to the Treasury bill market in assessing *ex ante* expected inflation rates, $EITB_{t-1}$, at the beginning of the period. However, these increasing increments of information about future real activity are built into the monthly, quarterly, and annual *conditional* expected inflation rates $EIMD_t$, estimated from the money demand models of inflation since the latter explain the *ex post* inflation rate in part in terms of future real activity. If, in going from the monthly to the annual data, $EIMD_t$ gains information about future real activity relative to $EITB_{t-1}$, then it follows that $UIMD_t = I_t - EIMD_t$, the conditional unexpected inflation rate from the money demand model, loses information relative to $UITB_t = I_t - EITB_{t-1}$, the unexpected inflation rate from the Treasury bill rate model. Consistent with the hypothesis that expected and unexpected inflation just proxy for future real activity in the stock return regressions, we then observe that in going from the monthly stock return regressions ($M1$) and ($M2$) to the annual regressions ($A1$) and ($A2$), $EIMD_t$ gains explanatory power relative to $EITB_{t-1}$, while $UIMD_t$ loses explanatory power relative to $UITB_t$. For example, the t-statistics for the estimated coefficient of $UITB_t$ go from -2.93 in the monthly regression ($M1$) to -4.01 in the annual regression ($A1$), whereas those for the estimated coefficients of $UIMD_t$ go from -2.80 in the monthly regression ($M2$) to $-.66$ in the corresponding annual regression ($A2$).

We can document more directly that the larger relative importance of $UITB_t$ in the annual data is due to a larger amount of information about future real activity in *ex post* annual unexpected inflation rates. In the monthly data, the correlation between $UIMD_t$ and $UITB_t$ is .90 (implying that the money demand and Treasury bill rate models make similar assessments of the one-month expected inflation rate), and both $UIMD_t$ and $UITB_t$ are uncorrelated with measures of future real activity. However, in the annual data, the correlation between $UITB_t$ and $UIMD_t$ is only .33, and $UIMD_t$, which is a conditional unexpected inflation rate net of the information in the future industrial production growth rate DPR_{t+1}, is uncorrelated with future real activity. On the other hand, $UITB_t$, which estimates a true annual unexpected inflation rate, has correlation $-.61$ with next year's industrial production growth rate DPR_{t+1}. The correlation $-.61$ is a measure of the information about future real activity available to price goods at the end of the year, and thus incorporated into $UITB_t$, which was not available to the Treasury bill market in assessing the expected inflation rate $EITB_{t-1}$ at the beginning of the year.

B. *Stock Returns and Expected Inflation*

Comparing the second and third regressions in the monthly and quarterly sections of Table 6 shows that replacing the conditional expected inflation rates $EIMD_t$ with individual explanatory variables (the annual growth rates of real activity and the monetary base) from the monthly and quarterly money demand inflation models produces large increases in the fraction of the sample variance of the real stock return which is explained. The increase in explanatory power

is even more substantial in the comparable annual regressions ($A2$) and ($A3$). Moreover, the growth rates of real activity and the base enter the real stock return regressions with much different relative importance than in the inflation regressions of Table 1. Current and past real activity are always important in the inflation regressions, but never have marginal explanatory power in the stock return regressions. Base growth rates are at least as important as future real activity growth rates in the inflation regressions, but future real activity growth rates dominate base growth rates in the stock return regressions. All of this suggests that expected inflation rates enter stock return regressions primarily because they happen to be functions of future real activity growth rates which are of more direct concern to the stock market.

Better evidence for this conclusion is, however, provided by the fourth and fifth regressions of each section of Table 6 which show that expected inflation rates never have marginal explanatory power in stock return regressions that also include base and future real activity growth rates as explanatory variables. In the case of $EITB_{t-1}$, these results imply that the most anomalous of the negative stock return-inflation relations, that between *ex post* real stock returns and *ex ante* expected inflation rates, has apparently been explained. However, we have more to say about stock return-expected inflation relations when we later consider the role of the base growth rate in the stock return regressions.

C. *Stock Returns and Unexpected Inflation*

The evidence in Table 6 on the relations between real common stock returns and unexpected inflation is less consistent. In the annual data, the explanatory power of the annual unexpected inflation rate $UITB_t$, observed in regression ($A1$), disappears when placed in competition with base and future real activity growth rates in regressions ($A5$) to ($A7$). On the other hand, the reliable negative relations between monthly and quarterly real stock returns and unexpected inflation observed in regressions ($M1$) and ($Q1$) are undisturbed, in terms of magnitudes of estimated regression coefficients and t-statistics, in the regressions ($M5$) to ($M7$) and ($Q5$) to ($Q7$) which also include BG_t and DPR_{t+12} as explanatory variables.

These negative relations between monthly and quarterly stock returns and unexpected inflation rates may reflect shortcomings of the real activity measures used in the monthly and quarterly inflation and real stock return regressions. The money demand inflation regressions produce consistently strong evidence for negative relations between inflation and real activity. However, what the monthly and quarterly inflation regressions call unexpected inflation may also be a response by the markets for goods to information about current and future real activity which is not captured by the specific measures of real activity used. If the stock market makes similar assessments of these omitted real variables, but with the predictable opposite price response, then negative proxy relations between stock returns and unexpected inflation can arise.

The measure of future real activity used both in the monthly and quarterly stock return regressions and in the monthly and quarterly inflation regressions is DPR_{t+12}, next year's rate of growth of industrial production. This choice is a somewhat *ad hoc* solution to problems caused by strong seasonals in real activity which show up neither in inflation rates nor in real stock returns. However, calculation of the annual growth rate of industrial production from one month or quarter to the next involves dropping the growth rate for the most recent month or quarter and adding that for the corresponding month or quarter one year ahead. These largely overlapping growth rates of industrial production may not do well in capturing the new information about future real activity which is used by the stock market and markets for goods in setting prices from one month or quarter to the next. In contrast, the nonoverlapping and largely serially uncorrelated annual growth rates of real output used in the annual stock return and inflation regressions may come closer to representing

the new information about future real activity used in setting prices on an annual basis. As a consequence, the annual growth rates of real output may leave less information about future real activity to be explained by unexpected inflation in the annual stock return regressions.

The monthly, quarterly, and annual regressions ($M7$), ($Q7$), and ($A7$) provide suggestive evidence on this point. If the explanatory variables in these regressions (the current unexpected inflation rate, the growth rate of the base, and the future growth rate of real activity), have roughly similar roles, the residual standard error $s(\varepsilon)$ in the quarterly regression ($Q7$) should be about $\sqrt{3}=1.73$ times that of the monthly regression ($M7$), while the residual standard error for the annual regression ($A7$) should be about $\sqrt{12}=3.46$ and $\sqrt{4}=2$ times those of the monthly and quarterly regressions. These projections stand up well in the monthly and quarterly data: $s(\varepsilon)=.071$ in ($Q7$) as compared to the value $.066=1.73(.038)$ projected on the basis of the residual standard error, $s(\varepsilon)=.038$, in regression ($M7$). However, the residual standard error, $s(\varepsilon)=.105$, in the annual regression ($A7$) is much lower than the residual standard errors, $.038(3.46)=.132$ and $.071(2)=.142$, predicted on the basis of the monthly and quarterly regressions ($M7$) and ($Q7$). This power of the annual regression occurs in spite of the fact that the monthly and quarterly regressions ($M7$) and ($Q7$) get substantial assistance from the unexpected inflation rate, $UITB_t$, whereas the future growth of real GNP, $DRGNP_{t+1}$, deprives $UITB_t$ of any marginal explanatory power in the annual regression ($A7$).

Since the direct results with respect to the unexpected inflation rate are mixed, it is well to take note of the somewhat different explanation of the relations between stock returns and unexpected inflation which is offered by Franco Modigliani and Richard Cohn. Their hypothesis is that the stock market is irrational. Nominal discount rates that vary directly with expected inflation are used by the market to price the real payoffs generated by equities. As a consequence, positive unexpected inflation, which implies higher future expected inflation in a world where expected inflation is approximately a random walk, produces a decline in stock prices and a negative relation between stock returns and unexpected inflation. However, a more direct implication of the particular market irrationality hypothesized by Modigliani and Cohn is that expected real stock returns should be positively related to the expected inflation rate. The stock return-expected inflation regressions reported here and elsewhere indicate uniformly that during the post-1953 period, the relations between expected stock returns and expected inflation rates are negative.[5]

D. *Stock Returns and Money Growth*

The results in Table 6 show that using base and future real activity growth rates to explain real stock returns kills the explanatory power of expected inflation rates. However, the fact that the variation in expected stock returns cannot be attributed to expected inflation does not erase the implication of regressions ($M1$), ($Q1$), and ($A1$) that the two variables move in opposite directions during the post-1953 period; in short, that expected real stock returns are reliably lower later in the period.

Moreover, although the first and sixth regressions in each section of Table 6 indicate that future real activity growth rates alone cut the coefficients of the *ex ante* expected inflation rates in half, regressions (5) to (7) of each section show that elimination of the expected inflation effect requires inclusion of the base growth rate in the regressions. These regressions also indicate that although the base growth rate seems to dominate the expected inflation rate, the two variables have a similar role. For example, the estimated coefficients of $EITB_{t-1}$ and BG_t in regressions ($M6$) and ($M7$), ($Q6$) and ($Q7$), or ($A6$) and ($A7$) have similar t-statistics, and substitution of BG_t for $EITB_{t-1}$ has little

[5]Since the expected inflation rate $EITB_{t-1}$ is an *ex ante* variable with respect to the real stock return RS_t, the regression of RS_t on $EITB_{t-1}$ estimates the relation between the *ex ante* expected component of the real stock return and the *ex ante* expected inflation rate.

effect on explanatory power. These results are not surprising in light of the strong relations between base growth rates and expected inflation rates implied by the money demand models of inflation in Table 1. Like expected inflation rates, base growth rates are highly autocorrelated (Table 4) and wander slowly from lower levels to higher levels during the post-1953 period.

There are, of course, models which propose causal relations between money growth and stock returns. For example, Robert Mundell and James Tobin propose models in which there are negative relations between expected real stock returns and either expected inflation rates or money growth rates. They hypothesize that the higher expected inflation rates caused by higher growth rates of money cause shifts from non-interest-bearing money to financial assets like common stocks, which lower the expected real returns on such assets. However, the hypothesized consequence of the lower expected real returns (costs of capital) caused by higher expected inflation rates is a boom in capital investment and real activity. This prediction is refuted by the consistent negative relations between real activity and expected inflation rates documented in Tables 1 and 2.

One could search for other economic interpretations of the stock return-expected inflation or base growth rate relations, but close examination of a few key regressions in Table 6 leads me to suggest a less profound explanation, in particular, that the relations are spurious. Thus, a time-series plot of the real stock return RS_t for the post-1953 period would show that real stock returns were on average higher during the 1950's than during the 1970's. Examination of the residuals from the regression (*A*9) of RS_t on $DRGNP_{t+1}$ would then show that although $DRGNP_{t+1}$ absorbs a substantial proportion (.68) of the variance of RS_t, it leaves some of the downward pattern of returns unexplained. Inclusion of the slowly wandering base growth rate BG_t in the regression (*A*8), however, has the effect of "twisting" the regression residuals toward lower values in the early years and higher values in the later years, thus producing residuals that are better scattered about zero than those from regression (*A*9). The plots are too cumbersome to show in a journal article, but the reader can observe in Table 6 that the residuals from regression (*A*9) are autocorrelated, whereas the residuals from regression (*A*8) show little autocorrelation.

While inclusion of BG_t in the real stock return regression twists the residuals so that they are better scattered about zero, the residuals from regression (*A*8) otherwise behave quite similarly to those from regression (*A*9) in which $DRGNP_{t+1}$ is the only explanatory variable. The reason BG_t has little effect on the residuals from the real stock return regressions is that, unlike the real stock return, the base growth rate is a highly autocorrelated variable (Table 4) that wanders rather smoothly from lower to higher values during the post-1953 period. Another variable of the same sort is the expected inflation rate $EITB_{t-1}$, which has a similar role in the inflation regressions. In fact, any variable that wanders slowly from lower to higher levels (or vice versa) would do a similar job in capturing the nonstationarity of expected stock returns which is left unexplained by measures of future real activity. For example, diagnostic checks showed that functions of time (time and time squared) replicate the effects of BG_t or $EITB_{t-1}$ in the stock return regressions.

Thus, the fact that BG_t dominates $EITB_{t-1}$ in the stock return regressions may not imply that there is a monetary rather than an expected inflation effect to be explained. The appropriate conclusion may be that the relations between real stock returns and either BG_t or $EITB_{t-1}$ are examples of spurious correlations of the sort first analyzed by G. Udney Yule. Specifically, there is nonstationarity in expected real stock returns which can be tracked by BG_t or $EITB_{t-1}$ but which is not caused by these variables. However, even a full guarantee that this viewpoint is correct would leave us with the uncomfortable fact that there is downward drift in expected real stock returns during the post-1953 period which is not fully explained by our story about real activity, or at

least by the particular real variables used to test the story.

V. Conclusions

The hypothesis of this paper is that the negative relations between real stock returns and inflation observed during the post-1953 period are the consequence of proxy effects. Stock returns are determined by forecasts of more relevant real variables, and negative stock return-inflation relations are induced by negative relations between inflation and real activity.

In many respects, the empirical tests of this model are successful. There is evidence that real stock returns are positively related to measures of real activity like capital expenditures, the average real rate of return on capital and output which we hypothesize reflect variation in the quantity of capital investment with expected rates of return in excess of costs of capital. There is also consistent evidence of negative relations between inflation and real activity which we interpret in the context of money demand theory and the quantity theory of money. Moreover, stock returns and inflation rates are most strongly related (though with opposite signs) to measures of future real activity. This is consistent with a rational expectations view in which markets for goods and securities set current prices on the basis of forecasts of relevant real variables.

The proxy effect hypothesis implies that measures of real activity should dominate measures of inflation when both are used as explanatory variables in real stock return regressions. In monthly, quarterly, and annual data, growth rates of money and real activity eliminate the negative relations between real stock returns and expected inflation rates. In the annual stock return regressions unexpected inflation also loses its explanatory power when placed in competition with future real activity.

There are other respects in which the empirical results are less supportive. In the monthly and quarterly data, future real activity does not explain the negative relations between real stock returns and unexpected inflation. There is suggestive evidence that this is due to the deficiencies of overlapping annual growth rates of real activity as measures of the new monthly or quarterly information used by the stock market to set prices. However, the evidence for this explanation is indirect, and the ritual call for further research is appropriate.

Perhaps most disappointing, although the anomalous negative relations between real stock returns and expected inflation rates largely disappear in the face of competition from measures of future real activity, complete explanation of the expected inflation effect occurs only when the base growth rate, a variable highly correlated with the expected inflation rate, is also included in the stock return regressions. Detailed examination of these regressions suggests that the relations between real stock returns and either the base growth rate or the expected inflation rate are spurious. However, this conclusion leaves us without an economic explanation for part of the documented decline in expected real stock returns during the post-1953 period.

Finally, the story told here about real stock returns is similar to that offered by Michael Gibbons and me for the behavior of the expected real returns on Treasury bills estimated from the wandering intercept inflation-interest rate regressions (2) and (4) of Table 1. As in the case of common stock returns, Gibbons and I found that expected real returns on bills vary negatively with expected inflation rates during the post-1953 period. However, contrary to the explanation for this phenomenon offered by Mundell and Tobin, Gibbons and I found that, as for common stocks, expected real returns on bills vary positively with measures of future real activity like output, capital expenditures and the average real rate of return on the capital stock. We conclude that equilibrium expected real returns on financial assets, like bills and common stocks, vary directly with desired capital expenditures in order to induce equilibrium allocations of resources between consumption and investment.

In short, the hypothesis for both common stocks and bonds is that expected real re-

turns are determined in the real sector. Spurious negative relations between inflation and expected real returns are then induced by a somewhat unexpected characteristic of the money supply process during the post-1953 period, in particular, the fact that most of the variation in real money demanded in response to variation in real activity has been accommodated through offsetting variation in inflation rather than through nominal money growth.

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Partial Adjustment in the Demand for Money: Theory and Empirics

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Central to the notion of money as the medium of exchange is the concept that all transactions are conducted using money balances. This notion, expounded most explicitly by Robert Clower (1967, 1970), has led to the development over the past decade of interesting models of the transactions and precautionary demand for money.[1] These have examined optimal behavior of the economic agent in steady state.

Although there has been much gained by examining money balance behavior in this way, money demand models so far have ignored the behavior of money during periods of disequilibrium. An adequate understanding of total money balances is possible only by incorporating both equilibrium and disequilibrium behavior into an overall view. In this regard, Michael Darby (1972) is exceptional in explicitly treating disequilibrium money demand behavior. Darby's paper is mainly empirical, but it contains an interesting intuitive discussion of money's role as a "shock absorber" during periods of disequilibrium.

In the present study, we address both the theoretical foundation and empirical importance of the shock absorber effect. We construct a model of optimal behavior by the economic agent, showing the necessary conditions for the existence of partial adjustment and indicating how the intensity of adjustment behaves over time and in response to changes in economic variables. This appears to be the first such attempt in the money demand literature, although there is related work in the investment literature on the flexible accelerator. We test the model on *U.S.* quarterly data to estimate the existence and magnitude of partial adjustment. We find a significant but small effect for both M_1 and M_2; furthermore, the effect dies out within one and two quarters for the respective definitions of money. The results thus support, but disagree in magnitude, with those of Darby (1972), who found a larger and longer-lasting partial adjustment effect. Our finding of so short an effect is especially important in light of Robert Barro's (1978) paper which relies on Darby's long-lasting effect to explain price behavior.

I. A Synthesis Model of Money Demand

A. *Equilibrium Behavior*

Assume the individual determines equilibrium cash balances according to precautionary demand theory, as expounded by Edgar Whalen.[2] As the result of an unspecified intertemporal maximization subject to lifetime wealth, the individual has determined a fixed expected real consumption expenditure. However, because of random elements in the billing process, in the availability of goods, and so on, the actual consumption expenditure may deviate from the expected, causing unexpected expenditures. These unexpected expenditures have a zero mean and some positive variance σ^2. As the volume of payments increases, so does σ^2, the nature of the increase depending on the probability distribution involved. The indi-

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[1]See Merton Miller and Daniel Orr, Robert Barro and Santomero, Santomero (1974) on transactions models, and Edgar Whalen and S. C. Tsiang on precautionary models.

[2]Precautionary balances can be held in conjunction with transactions balances, as in Tsaing, with no loss in generality of the approach in the text. In an earlier version, available from the authors, we also analyze a model with transactions balances only.

vidual holds precautionary balances to cover consumption expenditures. In determining his optimal level of precautionary balances, the individual must weigh the costs and benefits of such balances. On the one hand, the cost of precautionary balances is the interest earnings foregone by not holding a savings asset. If savings assets carry a nominal interest rate of r_A and money a nominal rate of r_M, then foregone interest earnings equal $M(r_A - r_M)$, where M is the amount of precautionary balances. On the other hand, the benefit of precautionary balances is avoidance of at least some illiquidity cost. If c is the dollar value of the illiquidity cost and p is the probability of illiquidity, then the expected illiquidity cost is $p\ c$. By Chebyshev's inequality, the probability that a variable deviates from its mean by more than k times its standard deviation is less than or equal to $1/k^2$. Defining $k \equiv M/\sigma$, then $p = \sigma^2/M^2$, assuming equality to be conservative.

The individual's problem now is to minimize the expected loss function[3]

$$L = M(r_A - r_M) + \frac{\sigma^2}{M^2} c \tag{1}$$

The optimal value of M, denoted M^*, is

$$M^* = \left[\frac{2\sigma^2 c}{r_A - r_M} \right]^{1/3} \tag{2}$$

B. *Disequilibrium Behavior*

As noted above, the equilibrium cash balances of equation (2) obtain when income and expenditure plans are consistent with expectations. In general, these balances do not result because, with unitary probability, unexpected expenditures are nonzero. Specifically, if the unexpected expenditures are negative, the individual receives a transitory positive shock to his money balances and finds himself with excess money balances. He would like to convert these excess balances into savings assets; however, he does not do so immediately. By definition, transitory shocks are unanticipated; consequently, upon receiving them, the individual is unprepared to dispose of them immediately and must spend time searching for appropriate assets to buy. Until such assets are found, the individual continues to hold his excess balances as money. We refer to these extra money balances as disequilibrium balances.[4] These extra balances gradually decline as desirable assets are found.

Given that the individual has determined his optimal equilibrium balances by considering, among other things, the return on alternative assets to money, there naturally arises the question of why the individual has to search out alternative assets. Shouldn't he already know quite a lot about them? At least two answers can be given.

First, because precautionary balances are held as a complement to transactions balances then presumably the only asset the individual knows much about and considers an alternative to cash is the short asset (such as a passbook account) that he regularly uses to store transactions balances for short periods of time.[5] This is not the asset in which he would want to store excess balances for this purpose, long assets and durable goods would be more appropriate. Because these assets are infrequently used, the individual will know little about them when he receives his excess balances.

Second, if information is costly to obtain, we may assume that the individual solves his loss-minimization problem at discrete points in time rather than continuously. In the intervening intervals, asset returns may vary both absolutely and relatively. If an infusion of excess balances is received during one of

[3]In fact, equation (1) should be solved simultaneously with the unspecified equations determining income and consumption. The simplifying assumption of sequential problems, frequently encountered in money demand models, is adopted here.

[4]The term disequilibrium means the deviation of the short-run money demand function from its long-run steady-state value. In particular, we assume that, because of adjustment costs, the individual chooses not to move his money balances immediately to their steady-state value so that a meaningful distinction between short- and long-run money demand can be made.

[5]Santomero (1974) has shown that there is in fact only one such asset in the standard transactions demand framework.

these intervals, the individual will be unwilling to commit such a relatively large amount of cash to any particular assets without first finding our what has happened to their rates of return.[6]

In this section of the paper, we present a precise theory of how assets are searched out and how excess money holdings are worked off.

1. *Behavorial Relations.* The individual is assumed to have an objective function which orders the choice set facing him in his attempt to allocate his excess balances among alternative financial assets. The first argument of this objective function is the loss that is experienced whenever actual average money holdings $M \geqslant 0$ differ from desired holdings M^*. Denote these deviations by $\tilde{M}$ or, in absolute value, $\hat{M}$:

$$(3) \qquad \hat{M} \equiv |\tilde{M}| \equiv |M - M^*|$$

Further, denote the difference between actual cash management loss L and the minimum loss L^* by $\tilde{L}$,

$$(4) \qquad \tilde{L} \equiv L - L^*$$

After substitution from equations (1) and (2) and some manipulation $\tilde{L}$ may be written

$$(5) \tilde{L} = \tilde{M}\left[(r_A - r_M) - \sigma^2 c \frac{2M^* + \tilde{M}}{\left[M^*(M^* + \tilde{M})\right]^2}\right]$$

Given that L^* is a global maximum, the value of $\tilde{L}$ is unambiguously positive and can be expressed as a general function of $\hat{M}$:[7]

$$(5') \quad \tilde{L} = h(\hat{M}, \ldots) \qquad h_1 > 0, h_{11} > 0$$

Thus whenever actual holdings deviate from desired, there are excess cash management losses.

To eliminate the excess loss $\tilde{L}$, the individual must eliminate disequilibrium money holdings $\hat{M}$ by buying or selling assets. In a world of costless information, such adjustments would occur immediately; however, when information is costly and when there are many assets with different characteristics,[8] the individual must spend time looking for appropriate assets to buy or sell. This search time is the second argument of the utility function. The individual derives utility from leisure and therefore attributes disutility to search.

The individual's utility at time t thus is a function of excess loss and search intensity; it is represented by

$$(6) \quad V = V\left[\tilde{L}(t), S(t)\right] \qquad V_{\tilde{L}} < 0, V_S < 0,$$

where $S(t)$ is the rate of search, measured in hours per unit of time. Using (5′), this function can be rewritten as a function of $\hat{M}(t)$ and $S(t)$; thus utility at time t can be written

$$(6') \qquad U = U\left[\hat{M}(t), S(t), \ldots\right]$$

We assume that V and therefore U are additively separable and concave in their arguments and obey the usual Inada conditions.

The individual can reduce $\hat{M}$ only by buying alternative assets. For analytical ease, it will be assumed that these assets all have the same risk-adjusted rate of return r_A, but have other relevant characteristics that can be discovered only by searching over assets. The harder he searches, the sooner he learns of these characteristics and the faster he can dispose of his excess money balances. Consequently, the behavior of $\hat{M}$ over time is governed by the following equation:[9]

$$(7) \qquad d\hat{M}/dt = f(\hat{M}, S) \leqslant 0,$$

[6]The possibility that transitory income is shifted to a short asset such as a passbook account for storage is treated both theoretically and empirically below. Essential to the scenario in the text is the assumption that individuals do not allocate transitory balances immediately to their optimal long-run positions.

[7]Equation (5) can be used for qualitative purposes only. Quantitatively, it would be misleading because L is not symmetric in $\hat{M}$. Positive values of $\hat{M}$ cause larger losses than negative values do. (However, for small values of $\hat{M}$, this asymmetry is small.)

[8]The agent may buy either a real or a financial asset. A dispersion of characteristics is easy to imagine for durable goods: horsepower, color, landscaping, etc. For financial assets, such things as risk, maturity, and income vs. growth potential seem important.

[9]Note that an aspect of adjustment is ignored in equation (7) and again in the optimization solution of

where $f(0,S)=0=f(\hat{M},0)$

$$f_1<0, f_{11}=0$$

$$f_2<0, f_{22}>0$$

$$f_{12}=f_{21}<0$$

The assumption that $f_{11}=0$ implies constant returns to scale of $\hat{M}$ in the $d\hat{M}/dt$ process. The assumption that $f_{22}>0$ implies diminishing returns to search. A simple example of a function satisfying these properties is

$$d\hat{M}/dt=-\alpha_0\hat{M}S^{\alpha_1}, \quad 0<\alpha_1<1$$

which is the standard geometric decay equation modified by search intensity and which can be shown to be a generalization of the common partial adjustment equation

$$(7') \qquad d\hat{M}/dt=-\Psi(\overline{M}-\overline{M}^*)$$

with $\Psi=\alpha_0 S^{\alpha_1}$. Thus examination of how S depends on various variables will reveal how the usual partial adjustment parameter also depends on those variables. In what follows, the more general specification of equation (7) is used.

2. *The Realism of The Behavioral Relationships.* The individual's optimization problem now can be solved to derive the optimal speed of adjustment. However, two aspects of the foregoing model of the individual's economic decision process warrant comment. First, the theory requires a rather strong assumption for there to be an empirically relevant partial adjustment of narrowly defined money, i.e., M_1: the individual must not convert transitory M_1 balances to a short savings asset for an appreciable length of time. Under some reasonable assumptions about the time-cost of transfers, for observed magnitudes of interest rates, and for small disturbances, the interest earned during the interval that the transitory income would be on deposit might not justify the cost of a special trip to the savings bank.[10] Note in addition that, for the individual, the period over which these transitory balances are held may be fairly short, perhaps a few weeks; but when these balances are spent, they become transitory income for someone else who then in turn holds them for a while, and so on. By such a multiplier process, the aggregate period of transitory money holding may become appreciable. Indeed, as discussed in the next subsection, Darby (1972) finds the period to be several years long. In any event, this assumption seems required for partial adjustment in M_1 demand. The assumption is less of a problem, of course, for M_2 demand. In the empirical work of Section II, we examine and compare the partial adjustment equation for M_1 and M_2.

Second, the model implies that excess money balances are disposed of gradually. It might seem more reasonable to assume that they are disposed of all at once after a period of search. In fact, given costly information, the optimality of such a once-and-for-all procedure is not obvious; its optimality depends on transaction costs, distribution functions, etc. Even if the once-and-for-all procedure should prove optimal, aggregation could justify the present framework as describing a "representative" or "average" individual's behavior.

3. *The Optimization Problem.* The individual's problem is to maximize his lifetime utility, given by

$$(8) \qquad \int_T^D U[\hat{M}(t), S(t), \ldots]\,dt$$

subject to equation (6) and the initial and terminal conditions

$$(9) \qquad \hat{M}(T)=\hat{M}_T, \hat{M}(D)=0$$

subsection 3 below. As shown later, an increase in $\bar{L}$ increases S, which increases the depletion of $\hat{M}$. An increase in $\bar{L}$ also leads the individual to settle for a lower value of the characteristics being searched out. This latter element also would increase the depletion of $\hat{M}$ but is held fixed in (7). The qualitative results appear to be unaffected by this simplification. See Seater (1977).

[10] For a detailed discussion and example of this case, which is covered in an earlier version of this paper, contact the authors.

where T is the initial time, D is the time of death, known to the individual.

The solution to this problem can be characterized with Pontryagin's maximum principle.[11] The Hamiltonian is

$$(10) \quad H = U(\hat{M}, S, \ldots) + \lambda f(\hat{M}, S)$$

Optimality requires that the following conditions hold:

$$(11) \quad \partial H/\partial S = U_2 + \lambda f_2 = 0$$

$$(12) \quad d\hat{M}/dt = \partial H/\partial \lambda = f$$

$$(13) \quad d\lambda/dt = -\partial H/\partial \hat{M} = -U_1 - \lambda f_1$$

$$(14) \quad \lambda(D)\hat{M}(D) = 0$$

and that (9) hold. Because of the concavity of equation (10) in $\hat{M}$, these conditions are also sufficient. Equation (11) states that the marginal benefits and costs of search must be equal. Equation (12) is simply a restatement of (6). The adjoint variable λ, which is negative, is the marginal value of $\hat{M}$, and equation (13) describes its motion over time. Equation (14) is the transversality condition.

Equation (11) can be solved to yield the function

$$(15) \quad S = \underset{(+)}{k}(\hat{M}, \underset{(-)}{\lambda})$$

where the sign under a variable is the sign of the partial derivative with respect to that variable. Equation (15) describes how S changes as $\hat{M}$ and λ move through time along their optimal paths. From (12), $\hat{M}$ steadily decreases, which, from (15), tends to cause a steady decrease in S. From (13), it is not clear whether λ, and thus S, initially grows or falls. However, on intuitive grounds, an increase in S seems unlikely so we ignore it for simplicity. Moreover, by (9), $\hat{M}$ falls to zero so that eventually S must fall, reaching zero exactly at time D.

In any event, the important points are that excess money balances are worked off only gradually and that the partial adjustment parameter Ψ of equation (7′) is not a constant but rather, as a function of S, changes over time with S.

4. *Comparative Statics.* We now examine how S responds to certain exogenous shocks. Such shocks change the entire optimal plan, including the function k itself. The individual can be thought of as making a new plan at every instant. If at time $(t+dt)$ all variables have changed as anticipated at time t, then the plan chosen at $(t+dt)$ coincides on the interval $[t+dt, D]$ with that chosen at time t; otherwise, the new plan differs from the old one. It is the nature of this difference that is of interest here.

Consider first an unexpected increase in $\hat{M}$. Such an increase raises the absolute magnitude of f_2, because $f_{21}<0$ by assumption, and throws (11) into inequality. It also increases the growth rate of λ, from (13). In response to this latter effect, λ must be made more negative. However, increasing the absolute magnitude of λ in this way exacerbates the inequality of (11). To restore inequality to (11), then, S must be increased. Thus in response to an unexpected increase in $\hat{M}$, S must increase. Exactly the opposite results hold for a decrease in $\hat{M}$.

Consider next a change in the interest rate differential $(r_A - r_M)$. Such a change affects the individual's optimal plan by altering $\tilde{L}$ just as changes in $\hat{M}$ do. However, the effect on $\tilde{L}$ and thus on the individual's response depends on whether M or $\tilde{M}$ is held constant. Both cases are interesting. If M, actual cash balances, is held constant, then it can be shown that

$$(16) \quad \left.\frac{\partial U}{\partial(r_A - r_M)}\right|_M = \frac{\partial V}{\partial \tilde{L}} \left.\frac{\partial \tilde{L}}{(r_A - r_M)}\right|_M \lesseqgtr 0 \text{ as } \tilde{M} \gtreqless 0$$

In contrast, if $\tilde{M}$, the difference between actual and desired cash holdings, is held

[11] Solving the problem this way treats (3) as a deterministic equation. In fact, as Seater (1977) shows, it is stochastic so that the optimization problem should be solved with stochastic control methods. Our use of deterministic control amounts to imposing certainty equivalence and ignores interesting stochastic aspects of the problem, such as behavior toward risk.

constant, then

$$(17)\quad \left.\frac{\partial U}{\partial(r_A-r_M)}\right|_{\tilde{M}}=\frac{\partial V}{\partial \tilde{L}}\left.\frac{\partial \tilde{L}}{\partial(r_A-r_M)}\right|_{\tilde{M}}<0$$

The same kind of arguments that were used above to analyze the response of S to changes in $\hat{M}$ can be used here. If M is fixed, then, as increase in (r_A-r_M) increases $\tilde{L}$ if $\tilde{M}>0$ and decreases $\tilde{L}$ if $\tilde{M}<0$. Thus if (r_A-r_M) increases, S increases if $\tilde{M}>0$ and decreases if $\tilde{M}<0$. If $\tilde{M}$ is fixed, than an increase in (r_A-r_M) increases $\tilde{L}$ irrespective of the sign of $\tilde{M}$, so that S also increases irrespective of the sign of $\tilde{M}$.

For analysis of individual behavior, (16) is a more useful result than (17) because it seems reasonable to suppose that M rather than $\tilde{M}$ remains fixed when (r_A-r_M) changes. For the aggregate empirical work that follows in Section II, however, (17) is the more useful result because it shows how monetary adjustment is affected by changes in (r_A-r_M) for a given amount of monetary disequilibrium.

Turning to the remaining exogenous variables, it is easily shown that the effect of changes in σ^2 and c on utility levels is directly dependent upon the sign of $\tilde{M}$ when N is held fixed but unambiguously positive when $\tilde{M}$ is held fixed. Thus, in response to an increase in either c or σ^2, S decreases if $\tilde{M}>0$ and decreases if $\tilde{M}>0$ when M is held fixed, and S always decreases when $\tilde{M}$ is held fixed.

$$(18)\quad S=S^E(\underset{(+)}{\tilde{M}},\underset{(sgn\,\tilde{M})}{(r_A-r_M)|M},\underset{(+)}{(r_A-r_M)|\tilde{M}},$$

$$\underset{(-sgn\,\tilde{M})}{\sigma^2|M},\ \underset{(-)}{\sigma^2|\tilde{M}},\ \underset{(-sgn\,\tilde{M})}{c|M},\ \underset{(-)}{c|\tilde{M}})$$

where the superscript E is a reminder that these results pertain to exogenous changes in the variables concerned, the symbol $x|y$ means "x given y", and *sgn* is the signum function. In Section II, a simplified version of (18) is incorporated into empirical estimates of the demand for money.

5. *Implications of the Model.* The foregoing model provides a general theory of partial adjustment by money demanders. When an individual receives excess balances, he does not convert them immediately into long-term assets because he has incomplete information on the assets available. Instead, he gradually reduces excess money holdings as suitable assets are found for transitory balances. Thus the individual's demand for money consists of two parts: a desired level, based on precautionary motives, and a partial adjustment component, reflecting gradual adjustment to transitory shocks. In the limit, that is, in steady state, money balances follow the precautionary demand models previously developed in the literature. However, outside of this position, money balances include the pure precautionary balances plus the balances associated with previous transitory shocks. The latter component decreases with time and can be modelled by a decaying lag on previous economic disturbances.

The intensity with which the individual reduces excess money holdings and approaches equilibrium changes with the time elapsed since the initial disturbance, as shown in (15), and varies in response to exogenous shocks to important economic variables, as shown in (18). Thus if disturbances to money holdings are modelled as a distributed lag on past transitory shocks, then the properties of that lag should change as the independent variables in (18) change. In particular, as $\hat{M}$ and $(r_A-r_M)|\hat{M}$ increase, the weights on the later terms of the lag should decrease, indicating faster adjustment. For increases in (r_A-r_M), the length of the lag may shorten, too. For increases in $\hat{M}$, the change in the length of the lag is less clear. The increase in S would tend to shorten the lag, but the increase in $\tilde{M}$ itself tends to lengthen the lag.

II. Estimation

A. *Estimating a Simplified Model*

The foregoing theory suggests that the demand for money function consists of two parts, one part being the equilibrium money demand and the other part being excess holdings resulting from partial adjustment to

past transitory shocks. Consequently, an additive functional form for current real money demand seems appropriate:

$$(19)\quad M_t^D = M^*(Y_{pt}, (r_t - r_M)_t, c_t) + M^T(\Sigma_t, \Sigma_{t-1}, \ldots, (r_A - r_M)_t, c_t)$$

where M_t^D is real short-run money demand, Y_p is real permanent income, M^T is real transitory balances resulting from partial adjustment, and Σ_{t-j} is the real shock to money balances in period $t-i$ for $j=0,1,2\ldots$.

Transitory shocks arise from two sources: flows in and out of actual money holdings and changes in desired holdings. Given the stability of the demand function over the sample period, however, we concentrate the analysis on the effect of transitory income on the demand for money. Indeed, because money is the medium of exchange, most transitory income other than capital gains would take the form of money flows. Two rather independent sources of transitory income are relevant as measures of shocks to actual money holdings. First, fluctuations in demand for output will result in income levels different from permanent income; so one element of transitory income will be deviations of observed income from its expected value, $Y_{tj} - Y_{Pt-j}$, where Y_{t-j} is current real income in period $t-j$. Second, unexpected money supply changes can alter income, as emphasized recently by Jack Carr and Darby and David Laidler (1969). Unexpected money balances placed in the hands of the public will be treated as an element of transitory income.[12] These unexpected money supply changes can be measured simply as the change in real money supply, $M_{t-j}^s - M_{t-j-1}^s$. If nominal money supply changes are anticipated, prices will adjust to maintain real money at its long-run level, assuming the demand for money is stable (an assumption with considerable empirical support). If, however, nominal money supply changes are unanticipated, prices will not adjust immediately and the real supply will differ from its long-run level. Thus actual changes in the real money stock are a measure of unexpected supply changes.

Because each term on the right side of equation (19) is nonlinear in the independent variables, the additive form of (19) is not amenable to the usual linear estimation techniques. Consequently, the following *log*-linear approximation is posited:

$$(19')\qquad M_t^D = M_t^*(1+D)$$

where the disequilibrium term D is a distributed lag on past transitory shocks and is given by

$$D = \sum_{j=0}^{N} Z^j \left[\frac{(Y_{t-j} - Y_{Pt-j}) + (M_{t-j}^s - M_{t-j-1}^s)}{Y_{Pt-j}}\right]$$

The two terms inside brackets are the two sources of transitory shocks discussed earlier, converted to proportional terms. This functional form for D assumes that all transitory income shocks, irrespective of source, have the same impact on money demand.[13] Nevertheless, this formulation is in some ways more general than those reported by Carr and Darby and Laidler (1979) in that it includes both real and monetary disturbances on the demand for money.[14] The particular form of the lag structure was chosen as the best-fitting one from among several shapes tried.

Thus the proposed equation to be estimated is

$$(20)\quad M_t^D = \alpha Y_{Pt}^{\beta}(r_{1t} - r_{Mt})^{\gamma_1} \ldots (r_{mt} - r_{Mt})^{\gamma_m} \left[1 + \sum_{j=0} Z^j \left(\frac{(Y_{t-j} - Y_{pt-j}) + (M_t^s - M_{t-1}^s)}{Y_{Pt-j}}\right)\right]^{\delta}$$

[12] The notion that changes in money supply should be treated as a component of income dates back to James Tobin (1965). Here we use the unexpected component as the determinant of money demand.

[13] One particular source of transitory income that could be especially troublesome is random shifts in money demand. However, a number of studies have shown the money demand function to be stable so that this source may be ignored.

[14] We have examined the model with disturbances occurring only as a result of deviations of income from

where r_i is the nominal rate of return on the ith asset and the following parameter signs are expected:

$$\alpha, \beta, \delta, >0, \ \gamma_1, \ldots \gamma_m < 0.$$

In the absence of the last term, (20) would be a standard form of the money demand function. The distributed lag term on transitory income attempts to capture the partial adjustment to past income disturbances that Darby (1972) calls the shock absorber effect. According to the theory of the previous section, the shape, length, and perhaps even elasticity (represented by Z, N, and δ, respectively) of the distributed lag term should depend on all the interest rate differentials $(r_i - r_M)$ and the magnitude of transitory income. A term with these properties would be difficult to formulate and estimate, so the simple form in (20) is used. Given this formulation, the null hypothesis on the lag elasticity is that $\delta < 1$, making the shock absorber term concave in transitory income. In this case, changes in transitory income have a less than proportional effect on disequilibrium money balances implying that more effort is devoted to quickly (i.e., within the current period) disposing of large shocks than to disposing of small ones, as implied by the theory.

B. *Results for* M_1

In estimating (20) it will be assumed that price movement is sufficiently rapid to eliminate deviations between demand and supply of money within the quarter. Therefore, real money balances may be used as a proxy for the short-run demand money. The rate of return on money r_M is set equal to zero.[15] As the rates of return on alternative financial assets, two interest rates are used, viz., the four to six-month commercial paper rate and the commercial bank passbook rate. All data are quarterly and are from the MPS model data bank obtained from the Federal Reserve Bank of Philadelphia.[16]

Estimation is by the Cochrane-Orcutt technique; *OLS* results suggested severe autocorrelation of the residuals. The parameters N and Z are found by iterative search to maximize the adjusted R^2. The results for the period 1952II–1972IV are, in *log* form,[17]

$$(21) \quad \log M_t^D = \underset{(0.49)}{2.08} + \underset{(0.075)}{0.47} \log Y_{Pt} - \underset{(0.005)}{0.014} \log RCP_t - \underset{(0.02)}{0.051} \log RCBP_t + \underset{(0.04)}{0.32} \log \left[1 + \sum_{j=0}^{1} (0.6)^j \times \left(\frac{(Y_{t-j} - Y_{Pt-j}) + (M_{t-j}^s - M_{t-j-1}^s)}{Y_{Pt-j}} \right) \right]$$

$$\bar{R}^2 = 0.9924, \ SSQR = 0.001888, \ \rho = 0.967, \ D.W. = 1.2$$

where RCP and $RCBP$ are the rates of return on four to six-month commercial paper and on time deposits. Standard errors are in parentheses below the estimated coefficients. All variables are significant at the 1 percent level.

The Durbin-Watson statistic is still low, even after first-order correction, suggesting higher-order serial correlation of errors. This would be expected with an independent variable constructed from a distributed lag series. Examination of the serial pattern of the errors strongly suggested a second-order process, so Durbin's method for second-order

its permanent level; our results were essentially the same as those reported below.

[15]Three different series on the rate of return on money were used without success. We attributed this failure to the poor quality of the data available, and the exclusion of other implicit prices on money balances. See Santomero (1979) for a discussion of these issues and data.

[16]Permanent income is generated by the usual *ad hoc* equation:

$$Y_{Pt} = aY_t + (1-a)(1+b)Y_{Pt-1},$$

where $a = 0.026$ is taken from Darby (1974) and $b = 0.0089$ is the quarterly growth rate of real *GNP*, found by regressing Y_t on time: $\log Y_t = c + b\ TIME$.

[17]Attempts to extend the model beyond 1972 failed because of the well-known shift in money demand that occurred around 1973. Investigation of this shift produced results no different from those of Stephen Goldfeld (1976), Carr and Darby, or virtually any other study of the post-1972 period.

correction was applied. The resultant coefficients were virtually the same as those reported in (21), including an almost-unchanged Durbin-Watson statistic. Thus, it appears that higher-order correlation than a second-order process is present in the data. Given this result, we decided to accept the results even though the standard errors may be underestimated. It should be recalled that, even though the reported standard errors may be too small, the point estimates themselves are unbiased.

The significance of the coefficient on the distributed lag supports the existence of partial adjustment in general and of Darby's shock absorber effect in particular. However, the shock absorber term is short-lived, lasting only two quarters; adding additional terms to the distributed lag worsened the fit. Because $\delta=0.32<1$, the shock absorber term is concave in transitory income in accordance with the null hypothesis that large transitory shocks will be disposed of more quickly than small ones. Interestingly, the shock absorber effect is of fairly small magnitude, even at its largest. Transitory income is never more than 10 percent of permanent income (and only rarely more than 6 percent). Even if transitory income is as large as 10 percent of permanent income two quarters in a row, the total percentage change in money balances in the first period is 3.1 percent. Next-period money balances rise by an additional 1.8 percent, so that the total shock absorber effect increases the demand for money by only 4.9 percent.

The coefficient on permanent income is much smaller than one, suggesting large economies of scale in money holding. This finding is at variance with the results of many other money demand studies, although it agrees with several more recent contributions, such as Goldfeld (1973) and Charles Lieberman (1977b). One interpretation of current models using transactions and precautionary demand theory is that the income elasticity should be less than one. However, if the expected illiquidity cost is the time involved in restoring liquidity or is proportional to total expenditures, then the income elasticity should be closer to unity for households and firms. The results reported here suggest that other sorts of costs may be pertinent or perhaps that technological innovation which is essentially a trend variable, and therefore correlated with income over time, is reducing the coefficient on income.[18]

The coefficient on *RCBP* is interesting. Its value of 0.05 is one-third the 0.15 value found in most earlier demand studies (Laidler, 1979). This reduction in the short interest rate elasticity stems entirely from serial correlation correction. In the uncorrected *OLS* fit, the *RCBP* elasticity was the usual 0.15. Lieberman (1977b) obtains similar large reductions in interest rate elasticities by correcting serial correlation in earlier studies.

C. *Comparison with Darby's Results*

Several of the findings differ considerably from Darby's (1972) original shock absorber results. Most important are the differences in the magnitude and duration of the shock absorber. Darby reports that "...[t]ransitory income increases the demand for money by about 40 percent of the amount of transitory income, and transitory money balances are worked off at a rate of about 20 percent per quarter" (p. 934).

The implication of Darby's results is that if transitory income were 10 percent of parmanent income, money demand would increase by 20 percent, even ignoring the effects of previous quarter's transitory income. As mentioned above, the results of the present study indicate that, when transitory income is 10 percent of permanent income, the *total* increase in money demand is 4.5 percent. Thus Darby's results indicate a much stronger shock absorber effect than we find.[19]

[18] Lieberman (1977a) finds that time, when entered as an independent variable to capture changes in technology, has a significant negative coefficient but apparently of a magnitude too small to explain our failure to obtain a unitary elasticity on income. Barro and Santomero find evidence of a larger technological effect but still apparently not large enough to account for our small income elasticity.

[19] Failure by Darby to correct for serial correlation apparently is not the source of these differences, for Darby checks his results using a generalized least squares estimate.

Also, Darby's 20 percent decay rate for transitory money balances indicates a much longer duration for the shock absorber than found in this study. According to Darby's results, it takes eleven quarters for transitory money balances to fall below 10 percent of their original level, whereas we find that transitory balances have completely disappeared within two quarters. Other differences between Darby's results and those reported here concern the income elasticity, which Darby finds to be one (double ours), and the short interest rate elasticity, which Darby finds to be 0.026 (half ours).

The major source of difference apparently is the form of the estimating equation. Darby's equation is linear with a lagged dependent variable, whereas ours is *log*-linear with serial correlation adjustment.[20] Because the latter follows from the equilibrium behavior of cash balances and has been used extensively in the literature, we favor the *log* form.

D. *Comparison with Goldfeld's Results*

It is informative to compare the present results with those of Goldfeld (1973). Goldfeld obtains the following estimate for the period 1952II–1972IV:

$$(22)\quad \log M_t^D = 0.271 + 0.193 \log Y_t + 0.717 \log M_{t-1} - 0.019 \log RCP_t - 0.045 \log RCBP_t$$

$$\bar{R}^2 = 0.995,\ SSR = 0.001197,\ \rho = 0.472,\ DW = 1.73$$

Note that Goldfeld uses current rather than permanent income and includes lagged money as an explanatory variable. There are two possible reasons for including these variables. One reason is partial adjustment; the other is the use of a Koyck transformation to estimate permanent income. Goldfeld interprets his results as deriving from partial adjustment; but if the permanent income interpretation is adopted instead, his interest rate coefficients are almost the same as ours. When equation (20) is estimated without the distributed lag term but including permanent income, one gets elasticities very similar to those in (21) and (22). The implication is that Goldfeld's equation would be interpreted more appropriately as deriving from the permanent income rather than the partial adjustment model.

E. *Results for M_2*

As remarked earlier, for our model to permit empirically significant partial adjustment of M_1 demand, one must make the strong and perhaps unrealistic assumption that the individual does not transfer transitory balances to a short savings asset quickly. Our empirical results suggest that this assumption may not hold. The assumption obviously is less important for partial adjustment of M_2 demand, so one might expect to see slower adjustment of these balances to transitory income shocks. Interestingly, the partial adjustment results are quite close to those for M_1. In particular, over the period 1952II–1976III, our estimate of the short-run demand for M_2 balances is

$$(23)\quad \log M_t^D = \underset{(0.27)}{-0.318} + \underset{(0.05)}{0.99} \log Y_{Pt} - \underset{(0.005)}{0.03} \log RCP_t - \underset{(0.028)}{0.044} \log RCBP_t + \underset{(0.04)}{0.37} \log\left[1 + \sum_{j=0}^{2} (0.5)^j \left(\frac{(Y_{t-j} - Y_{Pt-j}) + (M_{t-j}^s - M_{t-1-j}^s)}{Y_{Pt-j}}\right)\right]$$

$$\bar{R}^2 = 0.9991,\ SSQR = 0.003506,\ \rho = 0.932,\ D.W. = 1.08$$

All variables are significant at the 1 percent level with the exception of *RCBP*. We attribute its insignificant negative sign to a high correlation of this own rate with other open-

[20] There is some difference in estimation periods as well. Darby ends his sample at 1966IV whereas our sample period ends with 1972IV.

market interest rates. The parameters of the disequilibrium term are fairly close to the values obtained for M_1, implying a small shock absorber effect of short duration (three quarters in this case instead of two). If transitory income is as high as 10 percent of permanent income three quarters in a row, the antilog of the disequilibrium term is 1.061, implying a 6.1 percent increase in money demand.

III. Conclusions

In this paper we have constructed a general model of partial adjustment by money demanders. The major implications of the theory are that partial adjustment is theoretically reasonable and that the "partial adjustment parameter" is not constant but changes over time and in response to exogenous shocks, as summarized in equations (15) and (18).

Empirical examination of a simplified version of the theoretical model finds support for the theory. Transitory disturbances have a less than proportional effect on money demand, suggesting that more effort is spent on correcting large shocks than is spent on small shocks, as implied by the theory.

Partial adjustment of both M_1 and M_2 money demand is found to be statistically significant but to have a small effect that dies away within two or three quarters. These results conflict with those of Darby, who found a stronger and longer-lasting effect, but agree with those of Edgar Feige, who found that partial adjustment was an insignificant influence in annual models of money demand.

An important application of our results is to Barro's recent attempt to explain the response of prices to unanticipated money growth. Barro finds lags in this response of much too great a length to be explicable within the context of his model, and he appeals to Darby's shock absorber effect for an explanation. Our empirical finding of a very small and very short shock absorber effect suggests that such an explanation is inadequate and thus leaves open to question the correctness of Barro's theory of aggregate price determination.

Appendix

The loss function to be minimized in determining equilibrium precautionary balances is

$$L=M(r_A-r_M)+\sigma^2c/M$$

From the definitions of $\tilde{L}$ and L^*:

$$\text{(A1)}\ \tilde{L}=\tilde{M}\left[(r_A-r_M)-\sigma^2c\frac{2M^*+\tilde{M}}{\left[M^*(M+\tilde{M})\right]^2}\right]$$

Note that maximization of L requires

$$\partial L/\partial M=(r_A-r_M)-2\sigma^2c/M^3=0$$

Thus, the sign of the bracketed term in (A1) equals sign $\tilde{M}$. For $\tilde{M}$ small relative to $\tilde{M}^*$, $\tilde{L}$ has the following derivatives:

(A2)

$$\frac{\partial\tilde{L}}{\partial\tilde{M}}=\left[(r_A-r_M)-\sigma^2c\frac{2M^*+4M}{\left[M^*(M^*+\tilde{M})\right]^2}\right]$$

$$\gtreqless 0 \text{ as } \tilde{M}\gtreqless 0$$

$$\text{(A3)}\quad \left.\frac{\partial\tilde{L}}{\partial(r_A-r_M)}\right|_M=-\frac{\partial M^*}{\partial(r_A-r_M)}$$

$$\times\left[(r_A-r_M)-\sigma^2c\frac{2M^*+\tilde{M}}{\left[M^*(M^*+\tilde{M})\right]^2}\right]$$

$$+\tilde{M}\left[1+\frac{2M^{*2}+2M^*\tilde{M}-M^*}{6M^{*2}+12M^*\tilde{M}+6\tilde{M}}\right]$$

$$\gtreqless 0 \text{ as } \tilde{M}\gtreqless 0$$

$$\text{(A4)}\quad \left.\frac{\partial\tilde{L}}{\partial(r_A-r_M)}\right|_{\tilde{M}}$$

$$=\tilde{M}\left[1-\frac{M^{*3}+M^{*2}\tilde{M}+(\frac{1}{3})\tilde{M}^2M^*}{(M^*+\tilde{M})^3}\right]>0$$

$$\text{(A5)}\quad \left.\frac{\partial \tilde{L}}{\partial \sigma^2}\right|_M = -\frac{\partial M^*}{\partial \sigma^2} \times \left[(r_A - r_M) - \sigma^2 c \frac{2M^* + \tilde{M}}{[M^*(M^* + \tilde{M})]^2}\right] - \frac{c\tilde{M}}{[M^*(M^* + M)]^2}\left[2M^* + M - 2\frac{M^* + M}{M^* M^2}\right] \lesseqgtr 0 \text{ as } \tilde{M} \gtreqless 0$$

$$\text{(A6)}\quad \left.\frac{\partial \tilde{L}}{\partial \sigma^2}\right|_{\tilde{M}} = -\frac{\tilde{M}^2 c}{[M^*(M^* + \tilde{M})]^2} \times \left(\frac{M^* + (\frac{1}{3})\tilde{M}}{M^* + \tilde{M}}\right) < 0$$

$$\text{(A7)}\quad \left.\frac{\partial \tilde{L}}{\partial c}\right|_M = -\frac{\partial M^*}{\partial c} \times \left[(r_A - r_M) - \sigma^2 c \frac{2m^* + \tilde{M}}{[M^*(M^* + \tilde{M}]^2}\right] - \frac{\sigma^2 \tilde{M}}{[M^*(M^* + \tilde{M}]^2}\left[2M^* + M - 2\frac{M^* + M}{M^* M^2}\right] \lesseqgtr 0 \text{ as } \tilde{M} \gtreqless 0$$

$$\text{(A8)}\quad \left.\frac{\partial \tilde{L}}{\partial c}\right|_{\tilde{M}} = -\frac{\tilde{M}^2 \sigma^2}{[M^*(M^* + \tilde{M})]^2} \times \left(\frac{M^* + (\frac{1}{3})\tilde{M}}{M^* + \tilde{M}}\right) < 0$$

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Bargaining under Uncertainty

By W. CRAIG RIDDELL*

A number of solutions to the two-person bargaining problem have been proposed, the most well-known being that of John Nash. These solutions apply to situations in which there is no uncertainty about the payoff that each bargainer will receive from any particular agreement. However, in most bargaining situations, the payoff to each player will depend not only on the agreement that is reached but also on some external factors, the state of nature that obtains. Since this uncertainty about which state will occur may play an important role in the negotiations, this paper attempts to analyze such situations.

There are many examples of circumstances to which the theory developed here applies, and it is worthwhile mentioning a few of these. In firm-union bargaining, there will typically be uncertainty about the future rate of inflation as well as the state of the labor and product markets during the contract. In most court cases there is uncertainty about the outcome of the trial and about the judge's sentence in the event of a conviction; the two parties may therefore choose to negotiate an out-of-court settlement. Similarly, contractual arrangements such as sharecropping are the outcome of bargaining situations in which uncertainty plays a role. Also, the theory could be applied to the outcome chosen by an arbitrator or some other third party rather than that arrived at by the two bargainers.

In many bargaining situations it may be necessary for the negotiators to reach an agreement prior to the realization of the state of nature. This restriction is not imposed here; the two players are given the choice of reaching a prior agreement or of waiting until the state of nature reveals itself. Which of these two approaches will the bargainers choose? As long as the two bargainers differ in their attitudes toward risk (and assuming as I will do throughout the paper that neither is able to make insurance-type arrangements with a third party), then they can always make themselves better off (in an expectational sense) by reaching an agreement prior to the state being realized. The optimality of such a "prior commitment" strategy results from the fact that the differences in attitude toward risk imply gains from trade. When efficient, these prior agreements are an example of Pareto optimal insurance arrangements first analyzed by Karl Borch and Kenneth Arrow.

Differences in attitudes toward risk are sufficient, but not necessary, to imply that each party can benefit from a prior agreement. For example, two risk-averse individuals with identical attitudes will prefer such an arrangement if their payoffs in the absence of an agreement are negatively correlated.

In addition to the Nash axioms, a number of different sets of axioms are considered. In each case, these not only imply a unique solution to the standard two-person bargaining problem, but also to the problem examined here. The only additional assumption used to obtain a solution to the bargaining problem under uncertainty is that each bargainer can foresee the payoff that he will receive in each state.

The paper also examines the comparative statics effects of an increase in uncertainty on the bargaining solution. Such comparative statics predictions are potentially important in that they may allow one to test various alternative bargaining theories. In general, it is difficult to test these theories in terms of their predicted solutions alone, at least without employing simplified experi-

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mental conditions. (See Alvin Roth and Michael Malouf for a survey of experiments designed to test game-theoretic models of bargaining.) It turns out, however, that the comparative statics of the various solutions are very similar. Thus there is not much scope for distinguishing among bargaining theories in terms of the predicted response to an increase in uncertainty.

The comparative statics predictions regarding changes in uncertainty on the choices made by individual decision makers often depend on whether the individual displays decreasing, constant, or increasing risk aversion. (See, for example, Michael Rothschild and Joseph Stiglitz, and Larry Epstein.) It is therefore interesting that, in the situation examined here, the predicted effects of a change in uncertainty can often be signed without knowledge of the third-order properties of the bargainers' utility functions. Rather, the qualitative predictions depend on certain (generally observable) characteristics of the original risk-sharing agreement; in particular, on whether, as a result of the agreement, one party receives a more variable set of outcomes (i.e., acts as the insurer) and the other a less variable set.

The next section summarizes some of the solutions that have been suggested for the bargaining problem. Each of these solutions is implied by a set of "reasonable" axioms. The third section examines the bargaining problem under uncertainty, and shows that, together with the assumption mentioned above, each of these sets of axioms implies a solution to this more general problem. The fourth section examines the effects of an increase in uncertainty on the solutions. Conclusions are given in the final section.

I. Alternative Solutions to the Bargaining Problem

This section summarizes various game-theoretic solutions which have been proposed for the two-person bargaining problem.[1] The types of two-person cooperative games examined here are what are termed "fixed threat" games, the threat point being the no-trade solution. Each player has a von Neumann-Morgenstern utility function, denoted by $U_1(w_1)$ and $U_2(w_2)$, respectively, and each player is assumed to know the other's utility function.

A bargaining problem can be formulated as follows. Let $d=(d_1, d_2)$ denote the utility levels that players 1 and 2 will receive if they do not cooperate; thus d is the threat or disagreement point. Let $x=(x_1, x_2)$ represent the utility levels that the players will receive from a particular feasible agreement, and let S denote the set of all such feasible points. The set S, which can be called the utility possibilities set, is assumed to be a compact, convex subset of the plane. Convexity of S follows from the assumption of randomization of outcomes; that is, if two outcomes give rise to points x and y in S, then lotteries on these two outcomes will give rise to all linear combinations of x and y. It is assumed that bargaining is worthwhile (i.e., that there exists at least one point x in S such that $x>d$). Further, because the two parties would never agree to an outcome worse than the threat point, we can restrict attention to points x such that $x \geqslant d$.

A solution to the bargaining problem consists of a function f which selects a feasible outcome $f(d, S) \in s$ for each bargaining problem. The approach often taken to the bargaining problem involves specifying a number of reasonable axioms which the function f must satisfy. Nash specified the following axioms:

AXIOM 1: *Pareto optimality*. The point $x=f(d, S)$ must be Pareto optimal; that is, there is no $y \in S$ such that $y \geqslant x$ and $y \neq x$.

AXIOM 2: *Invariance with respect to positive linear transformations of utility*. The solution is not altered by order-preserving, linear transformations of the utility functions of either player; that is, given a solution $(x_1, x_2)=f(d, S)$ for any bargaining problem and given real numbers m, n, q, r such that $m, q>0$, then $f(mx_1+n, qx_2+r)=(mf_1(d, S)+n, qf_2(d, S)+r)$ where $f(d, S)=(f_1(d, S), f_2(d, S))$.

AXIOM 3: *Symmetry*. If the boundary of the utility possibilities set is symmetrical, then the solution will give equal utility increments

[1]For surveys of this literature see Robert Luce and Howard Raiffa, Robert Bishop, or Roth (1979).

to each party; that is, if $(x_1, x_2) \in S$ implies $(x_2, x_1) \in S$ and if $d_1 = d_2$, then $f_1(d, S) = f_2(d, S)$.

AXIOM 4: *Independence of irrelevant alternatives.* The solution to the bargaining problem does not change if the utility possibilities set is unfavorably altered such that the disagreement point is unchanged and the original solution remains feasible; that is, if (d, S) and (d, T) are bargaining problems such that $T \subset S$ and $f(d, S) \in T$, then $f(d, T) = f(d, S)$.

Nash's remarkable result was that these four axioms imply a unique solution to the bargaining problem, the point at which the product of the utility increments from the threat point are maximized. That is, the Nash solution is the point $x > d$ such that $(x_1 - d_1)(x_2 - d_2) \geqslant (y_1 - d_1)(y_2 - d_2)$ for all $y \in S$ such that $y > d$.

Several discussions of the Nash axioms are available (for example, Luce and Raiffa, and Bishop) so it is not necessary to discuss them further here. However, various alternative sets of axioms have been proposed. One axiom which warrants consideration is the following monotonicity axiom suggested by Guillermo Owen:

AXIOM 5: *Monotonicity.* If the utility possibilities set is favorably altered, then neither party should lose utility because of the availability of these new options; that is, let (d, T) and (d, S) be two bargaining situations with the same disagreement point such that $S \subset T$. Then $f(d, T) \geqslant f(d, S)$.

While this axiom appears quite reasonable, it is not compatible with Nash's axioms. This leads to two alternative sets of assumptions. In one of these, Axiom 2 is dropped; in the other Axiom 4 is dropped. Let us examine the latter case first. In order to do so, the following special form of the monotonicity axiom (due to Ehud Kalai and Meir Smorodinsky) is introduced:

AXIOM 6: *Individual Monotonicity.* If the utility possibilities set is altered such that for each level of utility that player 1 can obtain, the maximum feasible utility level for player 2 is increased, then the solution must involve

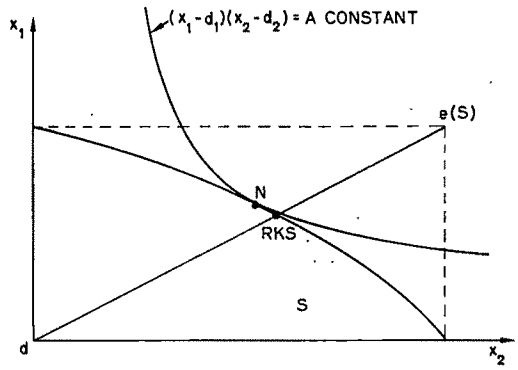

FIGURE 1

an increased utility level for player 2; that is, let $e(S) = (e_1(S), e_2(S))$ represent the "ideal point,"[2] $e_i(S)$ being the maximum utility that player i could receive from a feasible agreement, and let (d, S) and (d, T) denote bargaining situations such that $S \subset T$. Then if $e_1(S) = e_1(T)$, the solution must obey $f_2(d, T) \geqslant f_2(d, S)$.

Given Axioms 1–3, this individual monotonicity axiom is not compatible with Axiom 4, the independence of irrelevant alternatives other than the disagreement point.[3] Kalai and Smorodinsky give an example in which Axiom 4 is not reasonable, and suggest replacing Axiom 4 by Axiom 6 to remove this deficiency. More important, they prove that Axioms 1–3 plus 6 imply a unique solution to the bargaining problem. This solution, which I will call the Raiffa-Kalai-Smorodinsky (R-K-S) solution,[4] is obtained as follows. Draw a line from the threat point d to the ideal point $e(S)$. The solution is then the point at which this line intersects the boundary of the utility possibilities set. Figure 1 illustrates the Nash (N) and R-K-S solutions for a particular bargaining problem.

The other set of solutions results from dropping Axiom 2, the axiom of invariance

[2] $e_i(S) = max\{x_i | (x_1, x_2) \in S\}$. The term "ideal point" is that of Roth (1977).

[3] Roth (1977) shows that Axiom 5 is compatible with the following amended version of Axiom 4: *Axiom 4′: Independence of irrelevant alternatives other than the disagreement point and the ideal point.* If (d, S) and (d, T) are bargaining problems, and $e(S) = e(T)$, and $S \subset T$, and if $f(S, d) \in T$, then $f(S, d) = f(T, d)$.

[4] The solution was first proposed by Raiffa.

with respect to positive linear transformations of utility. Kalai investigates a class of "proportional" solutions (defined below) obtained without this axiom. In its stead he introduces the following homogeneity axiom:

AXIOM 7: *Homogeneity*. If the two utility functions are changed linearly by the same factor, the solution must also be changed by the same factor; that is, for every $k>0$, $f(kS)=kf(S)$.

This assumption, which treats the bargainers' utilities as comparable, is clearly a weaker axiom than Nash's Axiom 2. Kalai then goes on to show that, given Axioms 1 and 7, a solution obeys Axiom 5 if and only if it is a proportional solution. A proportional solution is defined as follows: f is proportional if there exist strictly positive constants c_1, c_2 such that for every bargaining problem S, $f(d,S)=\lambda(d,S)c$ where $c=(c_1,c_2)$ and $\lambda(d,S)=max\{t\colon tc\in S\}$. Figure 2 shows a proportional solution (PR) for two bargainers. Kalai also shows that a solution obeys Axioms 1, 4, and 6 if and only if it is a proportional solution. These sets of assumptions (either Axioms 1, 5, and 7 or Axioms 1, 4, and 6) do not give a definite solution point (as did the Nash and R-K-S axioms) since the proportions are not determined by the axioms. However, it is natural (in the spirit of Axiom 3) to normalize the utility functions such that the two players would gain equally from a symmetric bargaining situation. If this is done, then the proportional solution gives each player an equal utility gain in every bargaining situation.

An alternative solution involving interpersonal comparisons of utility was given by John Harsanyi.[5] He showed that, under certain conditions,[6] the outcome would maximize the weighted sum of the two players' individual von Neumann-Morgenstern utilities. The Harsanyi solution is shown as the point H in Figure 2.

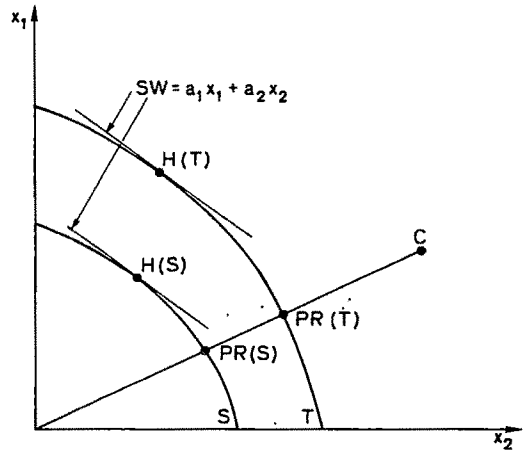

FIGURE 2

In summary, four alternative solutions to the bargaining problem have been discussed. These are not the only solutions which have been proposed; however, once these solutions have been extended to allow for uncertainty, the extension to other solutions will be straightforward.

II. The Bargaining Problem under Uncertainty

Uncertainty about which state of nature (or payoff matrix) will obtain is now introduced. Let the bargaining situation which the players would face if state s occurs be called subgame s. Each of these subgames is thus a fixed threat, two-person cooperative game; it will be assumed that one of the four sets of axioms discussed in the previous section holds and therefore that each subgame has a solution. Let $w_1(s)$ and $w_2(s)$ denote the payoffs that players 1 and 2 will receive if state s obtains. (Thus if, for example, the Nash axioms hold then $w(s)=(w_1(s),w_2(s))$ is the Nash solution in state s.) The players are assumed to foresee the payoff that each would obtain in each state. Some discussion of this assumption is provided below.

The players have the option of waiting until the state occurs or of commiting themselves to a prior agreement. Such an agreement, if reached, is binding on both players.

[5]Harsanyi did not deal specifically with the bargaining problem in that paper, but this is what his results would imply if applied to the bargaining problem.

[6]The requirements were (i) that the social welfare function $SW=\Sigma a_i x_i$ have the expected utility property, and (ii) that if two prospects are indifferent from the standpoint of every individual, they are also indifferent from a social viewpoint. In addition, the utilities are normalized so that if $x_1=x_2=0$ then $SW=0$.

The expected utilities of waiting are given by

$$(1) \qquad EU_1^* = \sum_s g_1(s) U_1[w_1(s)]$$

$$(2) \qquad EU_2^* = \sum_s g_2(s) U_2[w_2(s)]$$

where $g_i(s)$ is player i's subjective probability function over states of nature and E is the expectations operator.

We now show that the question of whether or not to enter into a prior agreement can be analysed as a bargaining problem (as defined in Section I) with the point $EU^* = (EU_1^*, EU_2^*)$ as the disagreement point. First, it is clear that neither player would agree to a prior commitment involving a payoff with expected utility less than EU_i^*. Further, payoff distributions with expected utility greater than EU_i^* can always be obtained from a prior agreement as long as the two bargainers differ in their attitudes toward risk. For concreteness, let player 1 be less risk averse than player 2. Then both can increase their expected utility above EU_i^* by an agreement which involves player 1 paying player 2 an amount $p(s)$ in state s such that player 2 receives a lower expected money payoff in exchange for a less variable one and vice versa for player 1. (Of course, $p(s)$ is negative in some states.) Steven Shavell provides a useful discussion of such payment plans, together with applications to indexation for uncertain inflation and payments subject to exchange rate uncertainty.

The set of feasible outcomes attainable through a prior agreement may be called the "prior agreements utility possibilities set." To complete the demonstration that the choice of such an agreement is a bargaining problem, this set must be shown to be convex. Consider first the intercepts of the frontier of the set. Let the ideal point for a given set of axioms be denoted by $E\hat{U}^* = (E\hat{U}_1^*, E\hat{U}_2^*)$. Then

$$(3) \quad E\hat{U}_1^* = \sum_s g_1(s) U_1[w_1(s) - p_1^*(s)]$$

$$(4) \quad E\hat{U}_2^* = \sum_s g_2(s) U_2[w_2(s) + p_2^*(s)]$$

where $p_1^*(s)$ is the payment schedule which maximizes EU_1 subject to the restriction $EU_2 = EU_2^*$ and $p_2^*(s)$ is the payment schedule which maximizes EU_2 subject to $EU_1 = EU_1^*$.

Convexity of the prior agreements utility possibilities set can be shown using an argument similar to that of Arrow (pp. 216–18). Consider the point b halfway between the two intercepts (i.e., $b = (1/2E\hat{U}_1^* + 1/2EU_1^*, 1/2E\hat{U}_2^* + 1/2EU_2^*)$) and consider the payment schedule $\bar{p}(s) = 1/2p_1^*(s) + 1/2p_2^*(s)$, all s. Since Mr. 1 is risk neutral or risk averse and Mr. 2 is risk averse,

$$(5) \quad U_1(w_1(s) - \bar{p}(s)) \geqslant 1/2U_1(w_1(s) - p_1^*(s)) + 1/2U_1(w_1(s) - p_2^*(s))$$

$$(6) \quad U_2(w_2(s) + \bar{p}(s)) > 1/2U_2(w_2(s) + p_1^*(s)) + 1/2U_2(w_2(s) + p_2^*(s))$$

Taking expectations of both sides of these two inequalities, it follows that the point b is in the interior of the set. This argument could be applied to any two points on the frontier of the set, thus establishing convexity.

The conditions for a payment plan to be Pareto optimal can be obtained from the following maximization problem:

$$(7) \quad \underset{\{p(s)\}}{Max}\ \alpha \sum_s g_1(s) U_1[w_1(s) - p(s)] + \beta \sum_s g_2(s) U_2[w_2(s) + p(s)]$$

where $\alpha \geqslant 0$, $\beta \geqslant 0$ and either $\alpha > 0$ or $\beta > 0$. The necessary conditions are

$$(8) \quad \alpha g_1(s) U_1'[w_1(s) - p(s)] = \beta g_2(s) U_2'[w_2(s) + p(s)]$$

for each s. When neither party is a risk preferrer, these are also sufficient. These conditions require that the bargainers' marginal rates of substitution between dollars in different states times their subjective odds of the states occurring be equal across states. When the two parties have the same

beliefs the conditions simplify to

$$(9)\quad \alpha U_1'[w_1(s)-p(s)]=\beta U_2'[w_2(s)+p(s)]$$

all s, the familiar conditions for optimal risk sharing.

Whichever one of the four sets of axioms is assumed, it now follows that these not only imply a solution (Nash, R-K-S, Harsanyi, or proportional) to each subgame but also to the more general bargaining problem under uncertainty. Of course, the shape of the prior commitments utility possibilities set will differ, in general, among these four sets of axioms but the results that the prior commitment strategy dominates and that the choice among prior agreements can be analyzed as a two-person bargaining problem will hold in each circumstance.

III. The Effects of an Increase in Uncertainty

The comparative statics effects of an increase in uncertainty on the negotiated prior agreement are examined in the section. A *ceteris paribus* increase in uncertainty is studied by having the probability function $g(s)=g_1(s)=g_2(s)$[7] undergo a mean preserving spread as defined by Rothschild and Stiglitz. Thus uncertainty is increased such that each player's expected (money) payoff is held constant. Further, note that the amount that player 1 receives if state s occurs, $w_i(s)$, is unaffected by the increase in uncertainty. Only the probability of state s occurring is affected.

Let $h(s)$ be a mean preserving spread of $g(s)$. Two asterisks will be used for outcomes associated with the probability function $h(s)$ and one for outcomes associated with $g(s)$. Thus the new disagreement point is denoted by $EU^{**}=(EU_1^{**}, EU_2^{**})$ where

$$(10)\qquad EU_i^{**}=\sum_s h(s)U_i[w_i(s)] \leqslant EU_i^* \qquad i=1,2$$

Similarly, $E\hat{U}^{**}$ represents the new ideal point and $p^*(s)$ and $p^{**}(s)$ refer to efficient payment plans given the beliefs $g(s)$ and $h(s)$, respectively. When it is necessary to denote a particular payment plan, one of the subscripts 1, 2, N, R-K-S, H, or PR is used; thus p_N^{**} is the Nash solution after the increase in uncertainty and $p_1^{**}(s)$ is the payment plan which maximizes EU_1 subject to $EU_2=EU_2^{**}$. Finally, E_g and E_h refer to expectations taken with respect to the probability functions $g(s)$ and $h(s)$, respectively, and w_i, p^*, etc. will be used in lieu of $w_i(s)$, $p^*(s)$ in much of what follows.

Before examining specific solutions it is useful to examine the overall effect of the increase in uncertainty on the prior agreements utility possibilities set. One point to note in this connection is that the necessary and sufficient conditions for a Pareto-optimal payment plan (given by equation (9)) remain the same when $g(s)$ is replaced by $h(s)$ in (7); that is for given weights α and β, $p^*(s)=p^{**}(s)$. (Note that this immediately gives the comparative statics of the Harsanyi solution as being $p_H^*(s)=p_H^{**}(s)$, all s.) Thus each payment plan which was efficient prior to the increase in uncertainty is also efficient after the increase, and to each point on the old frontier there is corresponding (in the sense that it is attained by the same payment plan) point on the new frontier.[8] Of course, both bargainers are worse off as

$$(11)\quad E_gU_1(w_1-p^*)\geqslant E_hU_1(w_1-p^*) = E_hU_1(w_1-p^{**})$$

and similarly for player 2. (The inequality is strict if player 1 is risk averse.) The slope of the frontier at these two points is the same; that is,

$$(12)\quad \frac{E_hU_1'(w_1-p^{**})}{E_hU_2'(w_2+p^{**})}=\frac{E_gU_1'(w_1-p^*)}{E_gU_2'(w_2+p^*)}=\frac{\beta}{\alpha}$$

[7]Allowing the two parties to have different beliefs would complicate this analysis considerably. Because differences in beliefs seem less fundamental and enduring than differences in attitudes toward risk, they are ignored in this section.

[8]Except that, as shown below (see equations (20) and (21)), some efficient payment plans in the original utility possibilities set are not contained in the new set because they become, to one of the players, worse than the disagreement point. Similarly, some efficient plans in the new utility possibilities set are not contained in the original set.

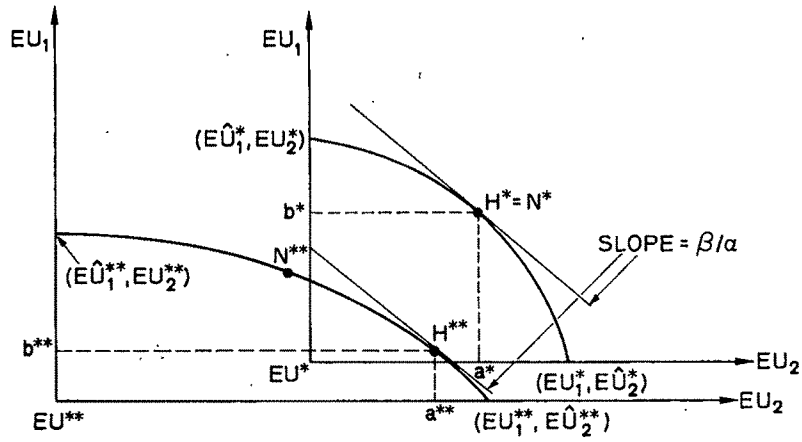

FIGURE 3

The effect of the increase in uncertainty on the expected gain from any efficient payment plan is also important in characterizing the new utility possibilities set. Let

$$(13)\ EG_1(w_1, p^*) = E[U_1(w_1 - p^*) - U_1(w_1)]$$

and similarly for $EG_2(w_2, p^*)$. Then, since a mean preserving increase in uncertainty reduces (increases) the expected value of a concave (convex) function (see Rothschild and Stiglitz),

$$(14)\quad E_h G_1(w_1, p^*) \gtreqless E_g G_1(w_1, p^*)$$

according to whether $U_1(w_1 - p^*) - U_1(w_1)$ is convex, linear, or concave, respectively, and similarly for EG_2.

The concavity or convexity of $[U_1(w_1 - p^*) - U_1(w_1)]$ and $[U_2(w_2 + p^*) - U_2(w_2)]$ depend on the nature of the original risk-sharing arrangement. If, in the absence of a payment plan, the outcomes are positively correlated then an efficient arrangement will typically involve a payment from the less risk-averse party (Mr. 1) to the more risk averse (Mr. 2) in "poor" states (i.e., $w_i(s) < Ew_i(s)di(s)$, $i = 1,2$) and a payment from 2 to 1 in "good" states. In this case (i.e., when Mr. 1 receives a more variable set of outcomes and Mr. 2 a less variable set and both are risk averse), $[U_1(w_1 - p^*) - U_1(w_1)]$ will be concave and $[U_2(w_2 + p^*) - U_2(w_2)]$ convex so that

$$(15)\quad E_h G_1(w_1, p^*) < E_g G_1(w_1, p^*)$$

$$(16)\quad E_h G_2(w_2, p^*) > E_g G_2(w_2, p^*)$$

This case is illustrated in Figure 3. (The points N^* and N^{**} can be ignored for now. The points H^* and H^{**} are attained by the same payment plan; $EU^*a^* < EU^{**}a^{**}$ from (16) and $EU^*b^* > EU^{**}b^{**}$ from (15).) A more precise statement of the conditions under which (15) and (16) hold is given in the Appendix. A sufficient condition is that $p^*(s) \gtreqless 0$ according to whether $w_i(s) \gtreqless Ew_i(s)$, $i = 1,2$. However, this condition is not necessary. A weaker sufficient condition, which will generally hold when $Cov(w_i(s), p^*(s)) < 0$, $i = 1,2$, is given in the Appendix.

An alternative arrangement of (15) is

$$(17)\quad E_g U_1(w_1) - E_h U_1(w_1) < E_g U_1(w_1 - p^*) - E_h U_1(w_1 - p^*)$$

That is, if the set of outcomes is more variable with an agreement than without, the utility of no agreement declines less in response to an increase in uncertainty than the utility of the agreement.

If $w_1(s)$ and $w_2(s)$ are negatively correlated then an efficient arrangement will typically involve a payment from Mr. 1 to Mr. 2 when $w_1(s) > Ew_1$ and $w_2(s) < Ew_2$ and vice versa. Thus the set of outcomes becomes less variable for each party so that (16) holds for Mr. 2 and

$$(18)\quad E_h G_1(w_1, p^*) > E_g G_1(w_1, p^*)$$

for Mr. 1.

A third case, in which an efficient payment plan implies a more variable set of outcomes for Mr. 2 and a less variable set for Mr. 1, is also possible. Because Mr. 2 is more risk averse, this situation is less likely to occur than the other two; it would occur, for example, when $w_2(s)=Ew_2$, all s, and Mr. 1 is risk averse. More generally, it holds when the correlation between $w_1(s)$ and $w_2(s)$ is close to zero and $w_1(s)$ is much more variable than $w_2(s)$. In this case (18) would hold for player 1 and

$$(19) \quad E_h G_2(w_2, p^*) < E_g G_2(w_2, p^*)$$

for player 2. The fourth case, in which (15) and (19) hold, is not possible.

Another set of results useful in characterizing the new utility possibilities set involves the best payment plans that each player can hope to obtain. As shown in the Appendix, when (15) and (16) hold, then

$$(20) \quad p_i^{**}(s) < p_i^*(s) \qquad i=1,2$$

That is, following the increase in uncertainty, each player's ideal payment plan involves a smaller payment from Mr. 1 to Mr. 2 in poor states and a larger payment from Mr. 2 to Mr. 1 in good states. On the other hand, when (18) and (19) hold then

$$(21) \quad p_i^{**}(s) > p_i^*(s) \qquad i=1,2$$

If we call the party that receives a more variable (less variable) set of outcomes the insurer (insuree), then (20) and (21) state than an increase in uncertainty favors the insurer in the sense that the insurer's ideal payment plan improves and the insuree's ideal payment plan worsens.

When the outcomes are negatively correlated, so that (16) and (18) hold, then the effect of the increase in uncertainty on the ideal payment plans cannot be signed without further information.

The special case in which player 1 is risk neutral is of some interest, in part because of the role it has played in the literature (for example, in the important papers by Martin N. Baily and Costas Azariadis) and in part because of the expositional advantages of

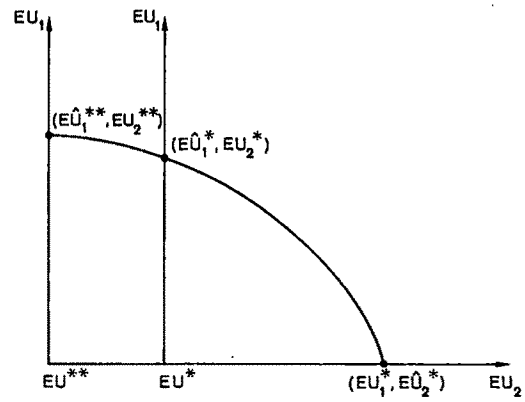

FIGURE 4

discussing this most easily visualized situation. In this case it follows from (9) or directly from Jensen's inequality that all Pareto-optimal payment plans will involve player 2 receiving a fixed payoff. These fixed payoffs range from $\bar{w}_2^* = w_2(s) + p_2^*(s)$ to $\bar{\bar{w}}_2^* = w_2(s) + p_1^*(s)$. Because Mr. 2's payoff is nonstochastic and because Mr. 1 is risk neutral, neither player's expected utility is affected by the increase in uncertainty. Thus the old and new frontiers coincide over the range $\bar{w}_2^*$ to $\bar{\bar{w}}_2^*$. Further, because $EU_1^{**} = EU_1^*$, player 2's ideal payment plan is not altered by the increase in uncertainty (i.e., $\bar{w}_2^{**} = \bar{w}_2^*$) whereas $EU_2^{**} < EU_2^*$ so that $\bar{\bar{w}}_2^{**} < \bar{\bar{w}}_2^*$. The effect of an increase in uncertainty on the utility possibilities set when player 1 is risk neutral is shown in Figure 4.

Turning now to the Nash solution, this is obtained from the following problem:

$$(22) \quad \underset{\{p(s)\}}{Max} \left[EU_1(w_1 - p) - EU_1(w_1)\right] \times \left[EU_2(w_2 + p) - EU_2(w_2)\right]$$

where expectations are taken with respect to $g(s)$. The necessary conditions are

$$(23) \quad U_1'[w_1(s) - p(s)] \cdot E_g G_2(w_2, p) = U_2'[w_2(s) + p(s)] E_g G_1(w_1, p) \quad \text{all } s$$

When neither player is a risk preferrer these conditions are also sufficient. $p_N^*(s)$ is the solution to (23). An increase in uncertainty

alters the second term on each side of this equation. When (15) and (16) hold, the left-hand side rises and the right-hand side falls so that $p_N^{**}(s)<p_N^*(s)$ is needed to restore the equality in (23). Similarly, when (18) and (19) hold, $p_N^{**}(s)>p_N^*(s)$. When both parties receive a less variable set of outcomes from an efficient payment plan (i.e., when (16) and (18) hold), the comparative statics of the Nash solution can't be signed without additional information.

Relative to the Harsanyi solution, the Nash solution implies that increases in risk do more harm to the player being insured by the risk-sharing agreement (the player receiving a less variable set of outcomes) and less harm to the insurer. This result is shown in Figure 3 for the case in which (15) and (16) hold, and where the weights α and β are chosen so that $p_H^*(s)=p_N^*(s)$.

The R-K-S solution leads to the same qualitative predictions as the Nash solution, that is, when (15) and (16) hold $p_{\text{R-K-S}}^{**}(s)<p_{\text{R-K-S}}^*(s)$, when (18) and (19) hold $p_{\text{R-K-S}}^{**}(s)>p_{\text{R-K-S}}^*(s)$, and when (16) and (18) hold the effect can't be signed without further information. The proof outlined here utilizes the fact that this solution is not altered by positive linear transformations of utility. Convenient utility representations are $V_1=m_1U_1+n_1$ and $V_2=m_2U_2+n_2$ such that

$$(24)\quad E_hV_i(w_i)=E_gU_i(w_i) \qquad i=1,2$$

$$(25)\quad E_hV_1(w_1-p_{\text{R-K-S}}^*)=E_gU_1(w_1-p_{\text{R-K-S}}^*)$$

$$(26)\quad E_hV_2(w_2+p_{\text{R-K-S}}^*)=E_gU_2(w_2+p_{\text{R-K-S}}^*)$$

Thus the old and new disagreement points coincide and the frontiers of the two utility possibilities sets intersect at the point given by the original R-K-S solution. Solving for m_1 and m_2 gives

$$(27)\quad m_i=\frac{E_gG_i(w_i,p_{\text{R-K-S}}^*)}{E_hG_i(w_i,p_{\text{R-K-S}}^*)} \qquad i=1,2$$

Suppose that (15) and (16) hold, so that $m_1>1$ and $m_2<1$. Now from (12) it follows

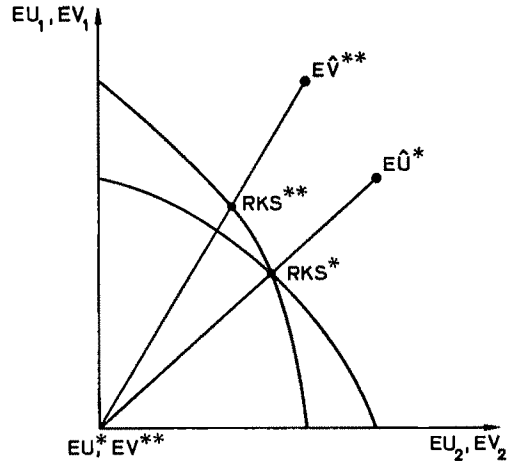

FIGURE 5

that

$$(28)\quad -\frac{E_gU_1'(w_1-p_{\text{R-K-S}}^*)}{E_gU_2'(w_2+p_{\text{R-K-S}}^*)}=-\frac{E_hU_1'(w_1-p_{\text{R-K-S}}^*)}{E_hU_2'(w_2+p_{\text{R-K-S}}^*)}.$$

The slope of the transformed frontier at this point is

$$(29)\quad -\frac{E_hV_1'(w_1-p_{\text{R-K-S}}^*)}{E_hV_2'(w_2+p_{\text{R-K-S}}^*)}=-\frac{m_1}{m_2}\frac{E_hU_1'(w_1-p_{\text{R-K-S}}^*)}{E_hU_2'(w_2+p_{\text{R-K-S}}^*)}>-\frac{E_gU_1'(w_1-p_{\text{R-K-S}}^*)}{E_gU_2'(w_2+p_{\text{R-K-S}}^*)}$$

Similarly, the slope of the transformed frontier at the point given by any efficient payment plan exceeds that of the original frontier for the same plan. Thus the two utility possibilities sets are related as shown in Figure 5 and $p_{\text{R-K-S}}^{**}(s)<p_{\text{R-K-S}}^*(s)$ follows.

When (18) and (19) hold the same argument can be used to show $p_{\text{R-K-S}}^{**}(s)>p_{\text{R-K-S}}^*(s)$.

Figure 6 illustrates the effect of an increase in uncertainty on the final solution discussed earlier, the proportional solution. Again, the weights α and β are chosen so

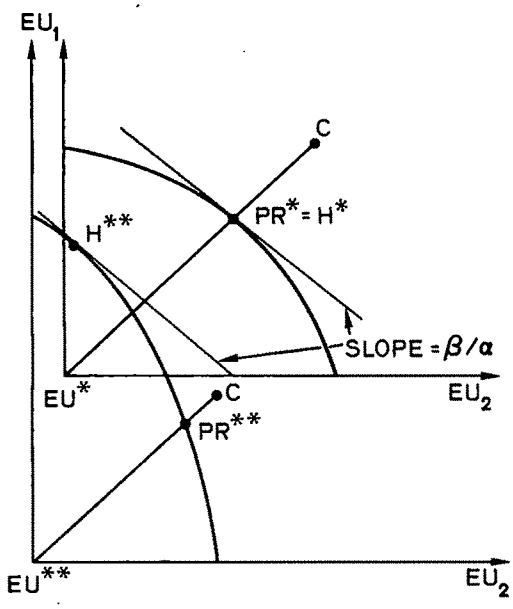

FIGURE 6

that H^* and PR^* coincide; however, this diagram applies to the case in which (18) and (19) hold. These two inequalities imply that the slope of the line from EU^{**} to H^{**} is greater than that from EU^* and H^*. But the proportional solution has the property that the slope of the line from EU^{**} to PR^{**} equals that from EU^* to PR^*. Thus $p_{PR}^{**}(s) > p_{PR}^{*}(s)$ in this case. Similarly, when (15) and (16) hold, $p_{PR}^{**}(s) < p_{PR}^{*}(s)$.

The results of this section are easily summarized. The Nash, R-K-S, and proportional solutions to the bargaining problem predict that an increase in uncertainty, *ceteris paribus*, will result in a prior agreement that is less favorable to the insuree and more favorable to the insurer. The insuree is thus unambiguously worse off while the insurer may be better off or worse off. When both parties receive a less variable set of outcomes from the original agreement, the effects of an increase in uncertainty cannot be predicted without additional information. The Harsanyi solution, on the other hand, predicts that the terms of the agreement will not respond to an increase in uncertainty so that both parties are unambiguously worse off.

Since three of the solutions make the same predictions there is relatively little scope for testing alternative bargaining theories in terms of the response to changes in uncertainty. On the other hand, it may be useful to know that the responses to changes in uncertainty that one would expect to observe are not very sensitive to alternative solutions to the bargaining problem.

IV. Conclusions

The purpose of this paper was to analyze the bargaining problem when there is uncertainty about what state of nature (or particular subgame) will obtain. This contrasts with the standard bargaining problem in which if any uncertainty exists at all it is confined to individual negotiators being uncertain about each other's behavior (for example, whether the other party will make a concession or not). It was found that the axioms which were sufficient to obtain a solution to the standard bargaining problem also imply a solution to this more general problem, providing we make the additional assumption that each player can foresee the solution to the bargaining problem in each state. This assumption allows us to "apply the axioms twice," first to each subgame and then to the choice of a prior agreement.

A number of authors have suggested that observed institutional arrangements may be accounted for by risk sharing; for example, Azariadis, Baily, and Donald Gordon with respect to labor market contracts, and John Gould and William Landes with respect to out-of-court settlements of lawsuits and criminal cases, respectively.[9] (Of course, negotiation costs and legal fees also play a role.) The contribution of this paper involves showing how specific solutions (rather than a set of efficient outcomes) can be obtained in these two-party situations.

It would seem worthwhile to extend the results of this paper to the case in which there are limitations on the parties' ability to make state-dependent payments. For example, in the case of lawsuits the negotiation of

[9]Gould indicates that approximately 95 percent of all lawsuits are settled out of court, and Landes reports that about 80 percent of all criminal cases receive negotiated sentences.

an out-of-court settlement typically implies that the state will not be observed. In other instances contracting costs make elaborate payment schedules unattractive.

The fact that the predicted effects of an increase in uncertainty depend primarily on certain generally observable features of the original risk-sharing arrangement should enhance the chances of empirical testing. Perhaps the most obvious data on which tests could be carried out are those involving changes in the terms of COLA clauses in response to changes in uncertainty about future inflation.

APPENDIX

1) *Derivation of conditions under which* (15), (16), (18), *and* (19) *hold*:

Concavity of $[U_1(w_1-p^*)-U_1(w_1)]$ can be established by showing that

$$\text{(A1)}\quad U_1[E(w_1-p^*)]-EU_1(w_1-p^*) > U_1(Ew_1)-EU_1(w_1)$$

Totally differentiating the right-hand side of (A1) yields

$$\text{(A2)}\quad d[U_1(Ew_1)-EU_1(w_1)] = \sum_s g(s)[U_1'(Ew_1)-U_1'(w_1(s))]\,dw(s)$$

Letting $dw(s)=-p(s)$, then a sufficient condition for (A1) and therefore (15) is

$$\text{(A3)}\quad \sum_s g(s)[U_1'(w_1(s)) - U_1'(Ew_1)]\,p^*(s)>0$$

Now if, for $i=1$,

$$\text{(A4)}\quad p^*(s)\gtreqless 0 \quad \text{according to} \quad w_i(s)\lesseqgtr Ew_i$$

then from risk aversion

$$\text{(A5)}\quad g(s)[U_1'(w_1(s))-U_1'(Ew_1)]\,p^*(s)\geqslant 0 \quad \text{all } s$$

with strict inequality for at least one s. Thus (A4) is sufficient but not necessary for (A1).

The weaker condition (A3) involves a covariance-type expression. In particular, each term of (A3) has the same sign as the corresponding term in

$$\text{(A6)}\quad -Cov(w_1, p^*) = -\sum_s g(s)[w_1(s)-Ew_1]\,p^*(s)$$

so that $Cov(w_1, p^*)<0$ *will generally imply* (A3).

The conditions under which (16), (18), and (19) hold can be obtained in a similar fashion. Also it should be noted that if

$$\text{(A7)}\quad Ep^*(s)\leqslant 0$$

which will certainly be the case if (A4) applies for $i=1,2$, then convexity of $[U_2(w_2+p^*)-U_2(w_2)]$ follows directly from

$$\text{(A8)}\quad U_2[E(w_2+p^*)]-U_2(Ew_2) < EU_2(w_2+p^*)-EU_2(w_2)$$

the left-hand side of (A8) being nonpositive from (A7) and the right-hand side being positive because $p^*(s)$ is an efficient payment plan.

2) *Proof of* (20) *and* (21):

Equations (15) and (16) state that

$$\text{(A9)}\quad E_h[U_1(w_1-p_2^*)-U_1(w_1)] < E_g[U_1(w_1-p_2^*)-U_1(w_1)]$$

$$\text{(A10)}\quad E_h[U_2(w_2+p_1^*)-U_2(w_2)] > E_g[U_2(w_2+p_1^*)-U_2(w_2)]$$

But by the definitions of $p_1^*(s)$ and $p_2^*(s)$, the right-hand side of (A9) and (A10) equals zero. Thus

$$\text{(A11)}\quad E_h[U_1(w_1-p_2^*)]<EU_1^{**}$$

$$\text{(A12)}\quad E_h[U_2(w_2+p_1^*)]>EU_2^{**}$$

which imply (20). The proof of (21) is similar.

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A Search Model of Real Estate Broker Behavior

By JOHN YINGER*

Despite their importance in the housing market, real estate brokers have received little analytical attention. Furthermore, real estate brokerage, like other businesses that deal largely in information, cannot be adequately explained by standard economic theory. As a result, our understanding of the market for real estate broker services and of the appropriate role for government in this market is severely limited.

An analysis of real estate broker behavior must consider uncertainty. A broker searches for buyers of housing and listings of houses for sale, but he (or she) cannot be certain about the number of buyers or listings that he will attract during any given time period. The matching of buyers with listings is also uncertain; because housing has many attributes and because tastes for these attributes vary widely, a broker knows that the matching of a particular buyer with a particular listing depends on random factors beyond his control, as well as on the asking price for the house. In this paper, I attempt to promote our understanding of the market for real estate broker services by constructing a formal model of the search-and-match behavior of brokers.

This paper draws on the literature about markets with imperfect information. A key feature of my model is an analysis of a broker's response to uncertain demand for his services. My approach to this issue is similar to the more general analysis of demand uncertainty provided by Dennis Carlton. I also examine the role of advertising in the market for real estate broker services. Not surprisingly, this examination raises several issues that have appeared in more general discussions of advertising, which are nicely summarized by William Comanor and Thomas Wilson. Although they are not the focus of my model, the responses of the buyers and sellers of housing to imperfect information are an important influence on the behavior of real estate brokers. My analysis of these responses draws on the general discussions of imperfect information by George Stigler and Michael Rothschild, and on the analysis of a housing market with imperfect information by Paul Courant.

My model differs from previous research in that it considers simultaneously three types of uncertainty facing real estate brokers: uncertainty about the number of buyers of housing; uncertainty about available listings; and uncertainty about matches between buyers and listings. The main premise of this paper is that these three types of uncertainty are crucial influences on real estate broker behavior. One unfortunate feature of the market for ideas about brokers is that this premise has no competitors—I have been unable to find any other formal analysis of real estate broker behavior. I hope that this paper will stimulate some of the needed competition. The paper is organized around three topics: a basic model of real estate broker behavior; an extension of this model to a market with a multiple listing service; and an examination of the potential role of government in the market for real estate broker services.

I. A Model of Real Estate Broker Behavior

Real estate brokers search for both buyers and sellers of single family houses. A broker tries to find sellers who will list with him (or her)—that is, who will authorize him to sell their houses—and then attempts to match buyers with his listings. When such a match is achieved, the broker receives a commission from the seller. To analyze the uncertainty in

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this process, let us make two key simplifying assumptions.

First, brokers try to influence the *average* price of housing but do not try to influence the *distribution* of housing prices. The price of housing is, of course, primarily determined by conditions in the housing market, but brokers, in their role as mediators between the buyers and sellers of housing, may have some impact on this price. Regardless of their impact on the average price, however, brokers set the relative prices of individual houses so that the probability that a buyer drawn at random from the pool of buyers will be willing to pay the asking price for a listing drawn at random from the pool of listings is constant. This probability, denoted δ, is a function of the average price of housing, V; i.e., $\delta=\delta(V)$. Another way to express this assumption is that there exists an hedonic function that, except for a random error, makes buyers indifferent across houses. Brokers try to influence the constant term for this function, but otherwise accept the household valuations of individual housing characteristics that are implicit in the hedonic function.[1] This assumption rules out the possibility that brokers treat different types of houses differently.

The second key assumption is that brokers consider each time period to be homogeneous. In practice, of course, the flows of buyers and listings into a broker's office are random variables and different buyers will have different numbers of listings to choose from. In my view, however, nothing important is lost by ignoring broker responses to this type of random variation. With homogeneous time, a broker's search for buyers affects his share of the flow of buyers during a time period, and a broker's search for listings affects his share of the average stock of listings in the system during the period. A broker uses his knowledge about these effects to choose the levels of search activity that maximize his income.

[1]This discussion implicitly assumes that the hedonic function observed in a housing market reflects household valuations of housing characteristics. As shown by Sherwin Rosen, this result depends on the further assumption that, except for a random error, households have the same preferences.

These two key assumptions imply that a broker treats each buyer independently. With no time variation in the stock of listings, each buyer who comes into a given broker's office will have the same number of listings to choose from. With all systematic differences in houses reflected in asking prices, there are no bargains or overpriced houses, and each buyer's chance of finding a house he wants is independent of the choices already made by other buyers. In more abstract terms, a broker acts as if each buyer confronts an independent random draw of listings from the total pool of listings in the system.

Suppose that the average stock of listings in the system during a time period, N_L, is known to each broker. The probability that a single broker will attract a randomly drawn listing is P_L, a function of that broker's search for listings, S_L, and of the rate of commission he charges, c. More search attracts more potential listings into a broker's office, so that $(\partial P_L/\partial S_L)$ is positive; a higher commission, like any price, discourages potential customers, so that $(\partial P_L/\partial c)$ is negative.

Now consider a potential buyer of housing who comes into a given broker's office. The probability that the broker can match that buyer with a listing drawn at random from the pool of listings in the system is equal to the probability that the broker will attract that listing, P_L, multiplied by the probability that the buyer will want to buy it, δ. Conversely, the probability that the broker cannot arrange that match is $(1-\delta P_L)$. The probability that the broker can match the buyer with at least one listing, and thereby obtain a commission, is equal to one minus the probability that he cannot arrange a match with any of the N_L listings in the system, or

$$(1) \qquad P_M=1-(1-\delta P_L)^{N_L}$$

The probability that a broker will attract to his office a buyer drawn at random from the pool of buyers, denoted P_B, is a function of a broker's search for buyers, S_B. Search attracts buyers, so $(\partial P_B/\partial S_B)$ is positive. The probability that a broker will arrange a

match with a randomly chosen buyer is equal to the probability that the broker will attract that buyer, P_B, multiplied by the probability that the broker will be able to arrange a match once the buyer has entered his office, P_M.

From the point of view of a single broker, therefore, the number of matches is a random variable with a binomial distribution for which the probability of success is equal to $P_B P_M$ for each buyer drawn from the pool of buyers. With a known flow of buyers through the system during a time period, N_B, the number of matches a broker expects to make, M, is the expected value of this binomial distribution or

$$(2)\quad M = N_B P_B P_M = N_B P_B\left[1-(1-\delta P_L)^{N_L}\right]$$

Because P_B is a function of the input "search for buyers" and P_L is a function of the input "search for listings," this equation can be thought of as the production function for the broker's output, namely matches between buyers and listings.

A. *The Real Estate Broker's Maximization Problem*

When a broker makes a match, he receives a commission cV, and pays the costs of completing the match, σ, which are the time costs needed to make the necessary calculations and arrangements. A broker's other costs are not directly connected to matches. He purchases units of search for buyers at a price r_B, and units of search for listings at a price r_L, and shows houses to prospective buyers. Because buyers will shop more carefully, and hence visit more houses, if V is higher, a constant showing cost per house implies that the showing cost per buyer, T_B, is an increasing function of V. Total showing costs equal T_B multiplied by the expected number of buyers, $P_B N_B$. A broker's expected income is equal to his total commissions (that is, his expected number of matches multiplied by his net commission per match) minus his search and showing costs. In symbols,

$$(3)\quad Y = (cV-\sigma)N_B P_B\left[1-(1-\delta P_L)^{N_L}\right] - r_B S_B - r_L S_L - T_B P_B N_B$$

The broker's problem is to choose c, V, S_B, and S_L so as to maximize this expected income; therefore, he sets

$$(4a)\quad \partial Y/\partial c = V\left[1-(1-\delta P_L)^{N_L}\right] + (cV-\sigma)N_L(1-\delta P_L)^{N_L-1} \times \delta(\partial P_L/\partial c) = 0$$

$$(4b)\quad \partial Y/\partial V = c\left[1-(1-\delta P_L)^{N_L}\right] + (cV-\sigma)N_L(1-\delta P_L)^{N_L-1} \times P_L(\partial\delta/\partial V) - (\partial T_B/\partial V) = 0$$

$$(4c)\quad \partial Y/\partial S_B = (cV-\sigma)N_B(\partial P_B/\partial S_B) \times \left[1-(1-\delta P_L)^{N_L}\right] - r_B - T_B(\partial P_B/\partial S_B)N_B = 0$$

$$(4d)\quad \partial Y/\partial S_L = (cV-\sigma)N_B P_B N_L \times (1-\delta P_L)^{N_L-1}\delta(\partial P_L/\partial S_L) - r_L = 0$$

When a broker raises c, he obtains larger commissions but also, because $(\partial P_L/\partial c)$ is negative, loses some sellers and therefore is less likely to make a match with each buyer. Equation (4a) indicates that a broker raises his rate of commission until the increase in the commission per match is offset by the lost income due to the lower probability of a match with each buyer. If the market for broker services is competitive and it is not costly for sellers of housing to find brokers, $(\partial P_L/\partial c)$ is negative infinity and the broker accepts the market-determined commission.[2]

A higher price for housing also raises commissions and, by lowering δ, lowers the probability of a match with each buyer. According to equation (4b), a broker raises the average price of housing until the increase in the commission per match is offset by the lost income due to both the decreased proba-

[2]As shown by Rothschild, high buyers' search costs can generate market power even if other conditions for a competitive market are satisfied. In our case, high search costs for the sellers of housing (the buyers of broker services) can generate market power for brokers.

bility of a match with each buyer and the increase in showing costs. If the housing market is competitive and it is not costly for buyers to find houses, $(\partial\delta/\partial V)$ is negative infinity and the broker has no influence on the price of housing.

Decisions about search activity form the heart of the broker's problem. Equation (4c) indicates that a broker increases his search for buyers until the return from another unit of search is offset by the cost. The marginal return from search is equal to the commission per match, $(cV-\sigma)$, multiplied by the number of potential matches, N_B, multiplied by the increased probability of a match due to higher search. The marginal cost of search is equal to the price of a unit of search plus the increased showing costs induced by that unit. Equation (4d) tells a similar story about search for listings. The marginal return from search is the income per match multiplied by the expected number of buyers multiplied by the increased probability of a match due to more search for listings; the marginal cost is simply r_L.

B. *Share Equations and Search Behavior*

To make our assumptions about broker search more concrete, let us say that S_B consists of newspaper advertisements that cost r_B per unit and that S_L consists of time spent contacting potential sellers at an opportunity cost of r_L per hour. Although real estate brokers undertake a variety of search activities, my own casual observations and most real estate textbooks indicate that these two types are by far the most important.

The search behavior of a broker depends on the impact of search on the share of buyers and listings the broker expects to attract. In practice, the shares P_B and P_L depend on many factors in addition to current search, including the broker's reputation and his search in previous periods. Using real estate firms as units of observation, an empirical study of brokers could therefore be built around share equations such as

$$\text{(5a)} \quad P_B = f(S_B, REP, AGE, SIZ)$$

$$\text{(5b)} \quad P_L = g(S_L, c, REP, AGE, SIZ)$$

where P_B is the firm's share of buyers during a time period, P_L is a firm's share of listings at a point in time (or its average share at several points during the period), REP is an index of the firm's reputation (as measured by a survey or by membership in a prestigious real estate organization), AGE is the number of years the firm has been in business (a proxy for past search), and SIZ is the number of brokers in the firm.[3]

Complex share equations like these are not tractable, however, in a formal model of broker behavior. Let us therefore make three simplifying assumptions. First, the system contains enough brokers that a single broker does not consider his influence on the average level of search. Second, all brokers are alike. Third, buyers and sellers are divided into two groups: people who have enough information to choose a broker before the period begins and people who use information provided during the period to choose a broker. A broker's share of the buyers or sellers in the first group depends on his reputation and previous search behavior. Buyers and sellers in the second group look for information about brokers and then choose a broker from the list of brokers of whom they have heard; consequently, a broker's share of the buyers (or sellers) in the second group is equal to that broker's share of the total units of search for buyers (or sellers) in the system.[4]

[3]The list of independent variables in these share equations is by no means exhaustive. The location of the firm's office, membership in a multiple listing service, and other factors could be included. Note that these share equations are powerful tools for studying real estate brokerage. For example, they help explain why brokers in white communities discriminate against blacks. Arranging sales to blacks damages a broker's reputation and thereby lowers his share of buyers and of listings; prejudiced whites will not deal with a broker who sells to blacks. Because P_L and P_B directly influence a broker's expected income, even a small amount of white prejudice makes it profitable for a broker to discriminate. For more on this point, see my report with Frederick Doolittle.

[4]This discussion reveals that search activities are, in part, an investment in future shares of buyers and listings. The one-period model in this paper does not consider the investment component of search. For a model of the way contacts increase over time, see Stigler.

To translate these assumptions into a share equation for buyers, note that a buyer may not find a house he wants to buy at the first broker he visits; on average, buyers will visit N_V brokers, where N_V is greater than one. Now if P'_B is the proportion of the buyers in the first group that a broker will attract based on his reputation and past search, α_B is the proportion of buyers that is in the second group, S^*_B is the average search for buyers undertaken by all brokers, and N_R is the number of brokers, then a broker's share of buyers in the current period can be written

$$(6)\quad P_B = N_V\left[(1-\alpha_B)P'_B + \alpha_B S_B / S^*_B N_R\right]$$

To determine the amount of search for buyers a broker will undertake, we must differentiate equation (6) with respect to S_B and substitute the result into equation (4c). If the resulting marginal benefit of search is greater than the marginal cost, the broker will increase his search. Other brokers, who are making the same calculation, will also increase their search, so that S^*_B will rise until marginal benefit equals marginal cost. By a similar argument, if the marginal benefit of search is below the marginal cost, S^*_B will fall until these two quantities are equal. The equilibrium level of search is found, therefore, by substituting the derivative of (6) into (4c) and solving for S^*_B:

$$(7)\quad S^*_B = S_B = (N_B N_V \alpha_B / N_R r_B) \times \left\{(cV-\sigma)\left[1-(1-\delta P_L)^{N_L}\right] - T_B\right\}$$

Equation (7) reveals that N_V and T_B are important determinants of search for buyers. The value of N_V is determined by buyer search behavior. A buyer of housing will search for another broker as long as the expected gain, namely the benefit from finding a house multiplied by the probability of finding one, exceeds the expected cost. With identical brokers, buyers expect the same gain at each broker, and buyer search for brokers is determined by the cost of such search. The cost of buyers' search may be influenced by broker search for buyers; the more advertisements placed by brokers, the less expensive it is for a buyer to find another broker and the more brokers a buyer will visit. Hence, N_V and S_B may be determined simultaneously. Without a detailed model of buyers' search behavior, which is beyond the scope of this paper, we cannot identify the impact of S_B on N_V and therefore cannot incorporate this simultaneity into our model. Instead, let us assume that N_V is fixed, but also conjecture about the implications of relaxing this assumption.

If buyers' search costs are very low, changes in broker search for buyers cannot influence N_V. In this extreme case, buyers continue to visit brokers until they have either found a house or visited all brokers. To analyze this case, remember that the probability of a match with a single broker is P_M, as given by equation (1). Now let $\rho = \rho(c)$ denote the proportion of listings that end up with brokers, so that $[1-(1-\delta\rho)^{N_L}]$ is the probability that a buyer can find a match in at least one broker's office. The maximum number of visits, N^*_V, multiplied by the probability of a match at each visit, P_M, must equal this ultimate probability, or

$$(8)\quad N^*_V = \left[1-(1-\delta\rho)^{N_L}\right]/P_M = \left[1-(1-\delta\rho)^{N_L}\right]/\left[1-(1-\delta P_L)^{N_L}\right]$$

Search for buyers also depends on showing costs per buyer, T_B. To determine showing costs, note that because δ is the probability that a buyer will match with a single listing, the number of listings needed for a match is a random variable with a negative binomial distribution. The mean of this distribution is $1/\delta$: on average, $1/\delta$ listings are needed to achieve a match. A buyer will visit only a fraction of the listings in a broker's files, so that a broker will not incur showing costs for each listing for each buyer. Suppose, however, that the expected showing cost per listing (i.e., the cost of showing the house to a buyer multiplied by the probability a randomly chosen buyer will want to visit it) is equal to t_B. Then t_B/δ is the expected showing cost *per buyer*. Because a buyer visits N_V brokers, each broker expects to pay showing costs of only $t_B/N_V\delta$ per

buyer; i.e.,

$$T_B = t_B / N_V \delta \tag{9}$$

Substituting (9) into (7) yields the following expression for search for buyers:

$$S_B = S_B^* = (N_B \alpha_B / N_R r_B) \times \{N_V (cV - \sigma)[1 - (1 - \delta P_L)^{N_L}] - t_B/\delta\} \tag{10a}$$

In the extreme case where N_V is defined by (8), (10a) becomes

$$S_B = S_B^* = (N_B \alpha_B / N_R r_B) \times \{(cV - \sigma)[1 - (1 - \delta\rho)^{N_L}] - t_B/\delta\} \tag{10b}$$

Sellers of housing search for a broker to sell their house. In choosing a broker, they compare the services a broker provides with the commission the broker charges. The principal service offered by a broker is to facilitate the sale of a house; because of their expertise and their access to buyers, brokers can be expected to sell a house more rapidly and at a higher price than can owners. In addition, a broker carries out, on behalf of the seller, the calculations and administrative chores required for a housing transaction. With all brokers alike, the rate of commission does not vary, and some proportion of sellers, $\rho(c)$, decide they will list with brokers at the market commission, where $(\partial\rho/\partial c)$ is negative. Sellers who do not value broker services enough to pay the market commission try to sell their houses themselves.[5]

Now if α_L is the proportion of sellers who pick their broker based on current information, and P_L' is a broker's share of sellers who use past information, then our assumptions about seller search imply that

$$P_L = \rho[(1 - \alpha_L) P_L' + \alpha_L S_L / S_L^* N_R] \tag{11}$$

[5]This paper does not attempt to model the behavior of sellers who do not list with brokers, or of buyers who do not find a match through a broker. For the most part, it does not matter whether sellers try to sell their houses themselves or return to the broker market in a later period. See, however, fn. 9 below.

Substituting the derivative of (11) with respect to S_L into (4d) and setting $S_L = S_L^*$ leads to the equilibrium level of search for listings:

$$S_L = S_L^* = (cV - \sigma) N_B N_V N_L \times (1 - \delta\rho/N_R)^{N_L - 1} \delta\rho\alpha_L / N_R^2 r_L \tag{12}$$

C. *Market Outcomes*

In this model with simplified search behavior, similar brokers, and no market power, we can examine several market outcomes, including the number of matches, the equilibrium commission, and the effects of entry into the real estate business. Remember that the demand for matches comes from the sellers of housing. The market for real estate broker services is in equilibrium if the demand for matches during the period equals the number of matches brokers can be expected to make during that period.

The demand for matches is equal to the number of listings introduced into the system during the period, H, multiplied by the probability that each listing will be given to some broker in the system, or

$$M^D = H \sum_{r=1}^{N_R} P_L^r \tag{13}$$

With all brokers alike, each potential seller visits a single broker, $P_L' = 1/N_R$, $S_L = S_L^*$, and the share equation for listings, (11), reduces to

$$P_L^r = P_L = \rho(c)/N_R \tag{14}$$

Market demand therefore simplifies to

$$M^D = \rho(c) H \tag{15}$$

This demand function is an ordinary downward-sloping function of the price c.

The supply of matches, that is, the number of matches brokers can be expected to make, is equal to the number of buyers multiplied by the probability that each buyer will find a

match with some broker, or

$$M^S = N_B \sum_{r=1}^{N_R} P_B^r P_M^r \tag{16}$$

With all brokers alike, $P_B^r = 1/N_R$, $S_B = S_B^*$, and the share equation for buyers, (6), becomes

$$P_B^r = P_B = N_V/N_R \tag{17a}$$

or. in the extreme case defined by (8),

$$P_B^r = P_B = \{[1-(1-\delta\rho)^{N_L}]/[(1-\delta P_L)^{N_L}]\}/N_R \tag{17b}$$

Substituting (1), (14), and (17a) or (17b) into (16) yields

$$M^S = N_B N_V[1-(1-\delta\rho/N_R)^{N_L}] \tag{18a}$$

$$M^S = N_B[1-(1-\delta\rho)^{N_L}] \tag{18b}$$

Equations (18a) and (18b) are unusual supply curves. In fact, $(\partial M^S/\partial c)$ is negative in both cases; that is, these supply curves are *downward* sloping.[6] As the rate of commission rises, fewer sellers decide to list with brokers, thereby lowering the probability of a match with each broker and decreasing the expected number of matches. Furthermore, broker search behavior does not influence the supply curve. According to (10a), a higher rate of commission leads brokers to undertake more search activity, but such an increase in inputs has no effect on market output, it simply reflects fiercer competition among brokers for potential matches. Finally, note that the supply curve for matches is unaffected by the input prices, r_B and r_L, or by closing costs σ, or showing costs t_B.

The analysis of market outcomes is more complex if N_V is influenced by broker search for buyers. Although a formal treatment of this case is not possible here, it is clear that this link between S_B and N_V could generate an upward-sloping supply curve. An increase in c still discourages some sellers from listing with a broker and thereby leads to a decrease in M^S. In addition, however, the increase in S_B caused by a higher c increases N_V and, according to (18a), increases M^S. The supply curve will be upward sloping if the second effect is stronger than the first. In contrast, broker search for listings cannot influence the supply of matches, because sellers list with a single broker regardless of the level of broker search. A dependence of N_V on S_B also implies that the supply curve is influenced by brokers' costs. According to (10a), changes in r_B, σ, or t_B (but not r_L) affect S_B, which, in turn, affects N_V and thereby shifts the supply curve.

The equilibrium commission and expected number of matches are determined by the condition $M^S = M^D$. This condition explicitly links the stock of listings held by brokers at a point in time, ρN_L, with the flow of listings into brokers' offices during the time period, ρH. If the supply of matches is greater than the number of new listings, the stock of listings will decline; if M^S is less than ρH, the stock of listings will increase. Neither of these situations is consistent with long-run equilibrium. Stability of the equilibrium requires that the supply curve be steeper than the demand curve, that is, that $|\partial M^S/\partial c| < |\partial M^D/\partial c|$. In this model, this condition is always met.[7]

Entry into the real estate business will occur until the income earned by a new broker is comparable to the income that a potential broker could earn in another business. By differentiating (18a) and (18b) with respect to N_R, we find that $(\partial M^S/\partial N_R) \leqslant 0$, where the equality holds only for (18b). Thus, unless buyers continue to shop until they find a match or have visited all brokers, entry actually *lowers* the supply of matches. By shifting the supply curve inward, entry

[6]Equations (18a) and (18b) show that M^S depends on c through $\rho(c)$. In both cases, differentiating with respect to c yields a positive term multiplied by $(\partial\rho/\partial c)$, which is negative. It follows that $(\partial M^S/\partial c)$ is unambiguously negative.

[7]Let $X = \rho\delta/N_R$. Because X is small, one can use the approximations $(1-X)^Y \cong e^{-XY}$ and $(1-X)^Y \cong (1-X)^{Y-1}$. Thanks to these approximations, the stability condition can be reduced to $N_L X < e^{N_L X} - 1$, which holds for all positive values of $N_L X$.

also *raises* the equilibrium commission. To understand these results, remember that adding brokers to the system spreads listings among more brokers and thereby lowers a buyer's chance of finding a match through a single broker. Therefore, unless buyers search until they have exhausted all listings, entry lowers each buyer's probability of finding a match and thereby lowers the expected number of matches.[8]

II. Real Estate Broker Behavior with Multiple Listing Service

When a broker cannot match a given buyer with any of his listings, he has an incentive to make a cobrokerage agreement with another broker. Under such an agreement, the broker tries to match the buyer with one of the other broker's listings and splits the commission with the other broker if a match is achieved. Similarly, if a broker has a listing that he cannot match with a buyer, he may want to turn to another broker for a buyer. The Multiple Listing Service (MLS) is an institution that formalizes cobrokerage for participating brokers.

The extent to which brokers rely on the MLS varies from place to place, but in many areas most residential real estate transactions now take place through some MLS. Furthermore, an MLS often requires member brokers to share all of their listings with the MLS, perhaps after a waiting period of a few days. It is appropriate, therefore, to examine a market in which all broker activity is routed through an MLS.

With an MLS, a broker's income flows through three channels. First, a broker matches some of the buyers who come to his office with his own listings. Expected income through this channel is analogous to expected income with no MLS and is equal to

$$(19a)\quad Y_1=(cV-\sigma)N_BP_B\left[1-(1-\delta P_L)^{N_L}\right]$$

Second, a broker who cannot match a given buyer with one of his own listings can attempt to match that buyer with the listings of other brokers who belong to the MLS. If the broker succeeds in making such a match, he receives some fraction, β, of the commission. Let us assume that he pays the same fraction of the closing costs. The probability of a match through this channel is the probability that the buyer will not find a match in the broker's own files but will find a listing elsewhere, or $[(1-\delta P_L)^{N_L}-(1-\delta^*\rho^*)^{N_L}]$. The asterisks indicate average values of the parameters for all brokers; from the point of view of a single broker, these values are fixed. Expected income through this channel is

$$(19b)\quad Y_2=\beta(cV-\sigma)N_BP_B \times\left[(1-\delta P_L)^{N_L}-(1-\delta^*\rho^*)^{N_L}\right]$$

Third, a broker's listings may be matched with a buyer by another member of the MLS. In this case, the broker receives a fraction, $(1-\beta)$, of the commission and (we assume) pays the same fraction of the closing costs. Each broker's share of such matches is equal to his share of the listings in the MLS. The probability that a broker will end up with this type of match with a randomly chosen buyer is equal to the probability that the broker will *not* attract the buyer, $(1-P_B)$, multiplied by the probability that the buyer will be "released" to the MLS by another broker and will find a match there, $[(1-\delta^*P_L^*)^{N_L}-(1-\delta^*\rho^*)^{N_L}]$, multiplied by the broker's share of listings, P_L. Hence, expected income through this channel is

$$(19c)\quad Y_3=(1-\beta)(cV-\sigma)N_B(1-P_B)P_L \times\left[(1-\delta^*P_L^*)^{N_L}-(1-\delta^*\rho^*)^{N_L}\right]$$

A broker attempts to maximize expected income through these three channels net of search and showing costs, or

$$(19d)\quad Y=Y_1+Y_2+Y_3-r_BS_B-r_LS_L-T_BP_BN_B$$

[8]A dependence of N_V on S_B weakens, but does not eliminate, the perverse impact of entry on M^S. By raising c, entry leads to more S_B and hence to a higher N_V and hence to an increase in M^S. This increase offsets to some degree the decline in M^S caused by the spreading out of listings among more brokers.

The first-order conditions for this problem with respect to c and V contain essentially the same lessons as the conditions without an MLS. The conditions with respect to search activity are

$$(20a)\quad \partial Y/\partial S_B=(cV-\sigma)N_B(\partial P_B/\partial S_B)\times\{1-(1-\delta P_L)^{N_L}(1-\beta)-\beta(1-\delta^*\rho^*)^{N_L}-(1-\beta)P_L\times[(1-\delta^*P_L^*)^{N_L}-(1-\delta^*\rho^*)^{N_L}]\}-r_B-T_B(\partial P_B/\partial S_B)N_B=0$$

$$(20b)\quad \partial Y/\partial S_L=(cV-\sigma)N_B(1-\beta)\times(\partial P_L/\partial S_L)\{P_BN_L(1-\delta P_L)^{N_L-1}\delta+(1-P_B)[(1-\delta^*P_L^*)^{N_L}-(1-\delta^*\rho^*)^{N_L}]\}-r_L=0$$

With an MLS, brokers still search until the expected marginal benefit equals the marginal cost; however, search now depends on the way commissions are split. Search for buyers increases as β, the fraction of the commission that goes to the broker with the buyer, increases; search for listings declines with β. A broker will not search for listings at all if β equals one, because his commission will be the same whether the buyers he attracts find a match in his own files or in the files of another broker in the MLS.

The introduction of an MLS leads to one major change in the search behavior of buyers; they never need to visit more than one broker because any broker gives them access to all the listings in the system. Setting $N_V=1$ and substituting the derivative of (6) with respect to S_B into (20a) leads to the search equation

$$(21)\quad S_B=(\alpha_BN_B/N_Rr_B)\{(cV-\sigma)\times\{[1-(1-\delta P_L)^{N_L}]+[\beta-(1-\beta)P_L]\times[(1-\delta P_L)^{N_L}-(1-\delta\rho)^{N_L}]\}-t_B/\delta\}$$

The share function for listings is not altered by an MLS. Substituting the derivative of (11) with respect to S_L into (20b) yields

$$(22)\quad S_L=[(cV-\sigma)N_B(1-\beta)\rho\alpha_L/N_R^2r_L]\times\{N_L(1-\delta\rho/N_R)^{N_L-1}\delta+(N_R-1)\times[(1-\delta\rho/N_R)^{N_L}-(1-\delta\rho)^{N_L}]\}$$

A. *Market Outcomes with an MLS*

Equation (16) describes the expected supply of matches with or without an MLS. The trick in analyzing market supply with an MLS is to recognize that P_M^r includes the probability of a match through only one of the second and third channels described earlier. Because a match through the third channel for one broker is a match through the second channel for another broker, including both channels would involve double counting.

The probability of a match through the first channel is $[1-(1-\delta P_L)^{N_L}]$, and the probability of a match through the second channel is $[(1-\delta P_L)^{N_L}-(1-\delta^*\rho^*)^{N_L}]$. With all brokers alike we can drop the asterisks and add these two probabilities to find that $P_M^r=P_M=[1-(1-\delta\rho)^{N_L}]$. Because each buyer goes to a single broker, $P_B^r=P_B=1/N_R$ and

$$(23)\quad M^S=N_BN_R(1/N_R)P_M=N_B[1-(1-\delta\rho)^{N_L}]$$

This downward-sloping supply function is identical to the supply function with no MLS for the case in which buyers search until they have exhausted all listings. Because an MLS does not influence the demand for matches, the equilibrium commission and quantity of matches with an MLS are also the same as in this special case with no MLS—the only case with no MLS in which each buyer has access to all listings. It follows from our previous analysis that with an MLS the equilibrium is stable and entry has no effect on

the expected quantity of matches or on the equilibrium commission.

In an MLS a broker can decide how to split the commission for his own listings. Maximizing (19d) with respect to β reveals that brokers with a high P_L will set β at zero and brokers with a high P_B will set β at one. However, a standard value or range for β usually arises through custom or through an explicit decision by the MLS. This outcome illustrates the importance of cooperation in the real estate business; a broker realizes that he cannot set an extreme value for β without antagonizing the brokers with whom he wants to share his listings or buyers. Nevertheless, the underlying economic incentives should influence the value of β. For example, the hypothesis that P_L is more heavily influenced by experience and prestige than is P_B implies that established brokers prefer a lower value of β than do new brokers. On the basis of this hypothesis one would predict that the observed value of β is a decreasing function of the dominance of an MLS by established brokers.

B. *Comparing the Market for Broker Services with and without an MLS*

To further understand the impact of Multiple Listing Services on the market for real estate broker services, let us compare our results with and without an MLS. In this analysis we will assume that the creation of an MLS does not change any of the parameters of the system, only the behavior of the market participants.

Except in the special case of low buyer search costs, an MLS increases buyer access to listings. If brokers do not have market power, that is, if they cannot influence c and V, the establishment of an MLS will therefore shift the supply curve outward and lower the equilibrium commission. With low buyers' search costs, M^S and c are the same with and without an MLS.

These results do not hold if brokers have market power. Suppose that setting up an MLS does not alter the degree of broker market power as measured by $(\partial P_L/\partial c)$ and $(\partial \delta/\partial V)$. In this case it can be shown that an MLS will have an indeterminate effect on c, but will increase V. If the establishment of an MLS leads to an increase in broker market power, then it is likely to increase c and will have an even larger positive impact on V.[9]

A switch to an MLS also affects broker search behavior. To keep the analysis manageable, let us compare search with an MLS to search without an MLS in the case described by (8). By focusing on this special case, we are comparing two systems in which buyers have access to all listings. To the extent that buyer access is limited without an MLS, our analysis will understate the differences between the two systems.

First, consider search for buyers. It follows from equations (10b) and (21) that if $\beta=1$, then total search for buyers, $N_R S_B r_B$, is the same in both systems. In all other cases, however, fewer resources are devoted to search with an MLS. To understand this result, remember that with an MLS each buyer visits a single broker. Consequently, brokers face a smaller pool of buyer visits, and a given amount of search attracts fewer buyers. If β equals one, however, the decrease in the pool of buyer visits is exactly offset by the income from matching buyers with other brokers' listings through the MLS. If β is less than one, the decrease in the pool is not completely offset by the new MLS matches, search for buyers is less productive, and less of it is undertaken.[10]

A comparison of search for listings under the two systems is more complex. Equations (12) and (22) imply that a value of β less than .25 guarantees that the total resources

[9]The impact of an MLS on c is found by assuming $(\partial P_L/\partial c)$ is constant and comparing (4a) with the first-order condition of (19d) with respect to c, which is not shown. The impact of an MLS on V is found by assuming $(\partial \delta/\partial V)$ is constant and comparing (4b) with the first-order condition of (19d) with respect to V, which also is not shown. A complete analysis of the impact of an MLS on V requires an analysis of the housing market as a whole and is therefore beyond the scope of this paper. For example, an MLS drives down the rate of commission and thereby increases the proportion of sellers who list with brokers. If sellers never try to sell their houses themselves, this effect represents an increase in the supply of houses and might therefore drive down the market price of housing.

[10]Comparing (10b) with (21) reveals that S_B is always lower with an MLS than without one.

devoted to search for listings, $N_R S_L r_L$, will be lower under an MLS. An MLS requires a broker to share his listings with other brokers, so that, in general, the productivity of search for listings is lower and less of it is undertaken. An MLS does increase the probability of a match, however, so that search for listings may be more productive under an MLS if the broker with the listing receives most of the commission. Because commissions usually are split fairly evenly, it is safe to conclude that the establishment of an MLS leads to a decrease in the resources brokers spend on search activity.[11]

This analysis is incomplete, however, because it does not account for entry. The creation of an MLS does not affect total commissions, but by lowering search activity it increases the income of individual brokers and thereby generates entry into the real estate business. As noted earlier, entry will not alter M^S or c and therefore will not alter total commissions. Furthermore, the entry will stop once income per broker, net of search, is equal to what it would be without an MLS. The only way for the same total commissions to be distributed to more brokers with no loss in net income per broker is for total search costs to decline. Even after entry, therefore, fewer resources are devoted to search with an MLS than without one.

A group of brokers will establish an MLS if they expect it to increase their incomes. This expectation depends on two effects of the MLS: the effects on search costs per broker and on commissions per broker. The first effect is clear-cut; an MLS lowers total search costs and thereby boosts brokers' incomes. An MLS affects commissions by changing the number of matches, the average value of housing, and the rate of commission. Unless buyer search costs are low, an MLS boosts commissions by raising the number of matches. Furthermore, if brokers have market power, an MLS boosts commissions by raising the average price of housing. On the other hand, unless buyer search costs are low or the MLS leads to a large increase in broker market power, an MLS lowers commissions by lowering the rate of commission. From a broker's point of view, therefore, the only possible disadvantage of an MLS is its effect on the rate of commission. Suffice it to say that the widespread establishment of Multiple Listing Services suggests that brokers do not expect an MLS to lower the rate of commission enough to offset its other effects.

My model also implies that membership in an MLS is a formidable competitive advantage. A member of an MLS with the same number of buyers and sellers as a nonmember has two additional channels for matches and can expect to make more matches and hence receive more income than the nonmember. Furthermore, this increase in match-making ability enhances a broker's attractiveness relative to nonmembers and thereby boosts his share of buyers and listings. It follows that the brokers who set up an MLS have a strong economic incentive to keep other brokers out of it. The numerous court cases brought against multiple listings services for restrictive membership requirements testify to the strength of these incentives.[12]

III. Public Policy Toward the Real Estate Business

Because the market for real estate broker services is so different from other markets, the usual presumptions about government intervention may not apply. In this section,

[11] The search equations (12) and (22) are difficult to compare. Defining $Q=\delta\rho N_L/N_R$ and using the approximations $(1-\delta\rho)^{N_L}\simeq 0$, $(N_R-1)/N_R\simeq 1$, and $(1-\delta\rho/N_R)^{N_L}\simeq e^{-Q}$, one can show that search for listings is greater with an MLS if $\rho>Q\{[1/(1-\beta)(1-e^{-Q})]-1\}$. Since, for small Q, $(1-e^{-Q})\simeq(1/Q)+.5$, a small Q approximation for this result is $Q>[1-\rho(1-\beta)]/(.5-\beta)$. For large Q, $(1-e^{-Q})\simeq 1$, so that a large Q approximation for this result is $Q<\rho[(1-\beta)/\beta]$. Combining these two approximations yields the conclusion that S_L is greater with an MLS only if $[1-\rho(1-\beta)]/(.5-\beta)<Q<\rho(1-\beta)/\beta$. With $\rho=.9$, for example, this condition can be met only if $\beta<.31$. This value is a slight overestimate because of the approximations used in the derivation. An appropriate summary of these results, therefore, is that a necessary condition for S_L to be greater with an MLS is that β be less than about .25.

[12] For a discussion of court cases involving MLS membership requirements, see my report with Doolittle.

we will ask what role the government has to play in this market.[13]

A. *The Optimal Level of Broker Search*

One key set of policy issues flows from the conclusion that a cut in search activities by all brokers might have no effect on the expected number of matches or on the equilibrium commission. This result suggests that, to some degree, search activity by brokers may represent competition among brokers for a fixed number of potential matches—not a productive use of society's resources. If so, something is inefficient about the market for real estate broker services and government may need to intervene.[14]

My model without an MLS suggests that the level of broker search is too high. A decrease in search activities by brokers would have no short-run effect on the expected number of matches or on the equilibrium commission. This conclusion must be qualified, however, for two reasons. First, my model assumes that S_B does not influence N_V. If this assumption is not justified, then a cut in broker search for buyers could lead to a decline in the expected number of matches. Second, a decline in broker search might be offset, to some degree, by increases in search costs for the buyers and sellers of housing. With fewer newspaper advertisements, a buyer would have more difficulty identifying brokers with the type of listings he wanted and would make more unproductive visits to brokers. With fewer contacts to reveal which brokers offered the highest likelihood of a match, a seller would devote more of his own resources to finding a broker. Thus, we cannot determine optimal broker search without an explicit model of buyer and seller search.

The establishment of an MLS reduces the inefficiency in the market for broker services because it leads to a decline in brokers' search activities without lowering the expected number of matches. Ironically, however, an MLS does not weaken the case for government intervention. Even with an MLS, a reduction in broker search activity would lower the resources devoted to search without altering the equilibrium commission or the expected number of matches. Furthermore, this decline is not likely to be offset by changes in N_V or by increased search costs for buyers and sellers. An MLS gives each buyer access to all listings through a single broker and gives all brokers the same access to buyers. Therefore, buyers and sellers have little incentive to visit more than one broker, and their search will be largely unaffected by a decline in broker search.

In short, my analysis suggests that the optimal level of broker search is less than the level generated by an unregulated MLS. A more precise determination of this optimal level or of the public policies needed to obtain it is beyond the scope of this paper.

B. *Antitrust Action*

Broker market power drives commissions and housing prices above the competitive level. The existence of broker market power would be, therefore, another reason for government intervention in the market for real estate broker services.

The available evidence implies that brokers have considerable market power. First, several authors, beginning with Stigler, have argued that in a market with imperfect information the existence of a single price indicates market power; competition should lead to price variation. The fact that the rates of commission charged by brokers are remarkably uniform suggests, therefore, that brokers

[13]An intriguing policy question suggested by my model is the optimal value of β. As β goes from zero to one, brokers shift the focus of their search from listings to buyers without affecting the total number of matches. Hence, a policymaker might want to set β so as to minimize resources devoted to search, $(N_R S_B r_B + N_R S_L r_L)$. Using the search functions (21) and (22), it can be shown that the optimal value of β is unity (zero) as $(\delta\rho N_L/N_R)$ is greater than (less than) $[(\alpha_B/\alpha_L)-\rho]$. Unfortunately, however, this condition has little intuitive appeal and depends on the values of parameters about which we currently know very little. A satisfactory answer to this question must await further research.

[14]This argument appears in more general form in Comanor and Wilson: "...where advertising messages are directly offset by those supplied by competing firms, the economic effect of these messages is nill and there are few social gains from these efforts. The information required for these market results could be provided at lower social costs and economic efficiency improved" (pp. 250–51).

have some market power. For example, Bruce Owen and Joseph Grunfest found that 75 percent of all residential real estate transactions in California involved a commission of exactly 6 percent.[15]

Second, expressing commissions as a percentage of house value is price discrimination, which could not persist without considerable market power. The service provided to a seller by a broker is to find a buyer and to finalize the sale. The cost of this service is, at best, only marginally related to the value of the house involved, but higher-income households, who of course buy more expensive houses, are willing to pay more for this service. A percentage commission translates this higher willingness to pay into a higher commission and is therefore, by definition, price discrimination. Competitive forces in the market for real estate broker services apparently are not strong enough to overcome the longstanding tradition of expressing commissions as a percentage of market value—that is, of price discrimination.[16]

Finally, my analysis of share equations, such as (5a) and (5b), suggests that newspaper advertising and contacts in a community have cumulative effects; a real estate firm with an established reputation is more profitable than a new firm. This result links my analysis of real estate brokerage with the literature on advertising and market power. As demonstrated by Comanor and Wilson, when advertising boosts profit rates, it contributes to the development of market power.

Broker market power is also an important factor in evaluating an MLS. My analysis indicates that, without broker market power, the creation of an MLS represents an unambiguous gain to society. It follows that the government should encourage MLSs, perhaps, where necessary, to the extent of providing loans and technical advice to help them get started. The existence of broker market power alters this conclusion, because the welfare gains from an MLS may be offset by increases in commissions and in the price of housing. Any encouragement of MLSs should therefore be accompanied by vigorous enforcement of antitrust laws.[17]

Access to an MLS is a key factor in insuring competition among brokers. As explained earlier, membership in an MLS, like an established reputation, is a source of market power, and the members of an MLS have a strong incentive to restrict access to it. To promote competition and reap the efficiency gains made possible by an MLS, any broker willing to pay the marginal cost of his membership should be allowed to join an MLS. Several court cases have knocked down arbitrary requirements for MLS membership, and the National Association of Realtors prohibits certain restrictive membership requirements for any MLS affiliated with it. Nevertheless, access to an MLS is often limited, and removing barriers to access

[15]The numerous price-fixing cases brought against real estate brokers, which are described by Owen and Grunfest, provide further evidence of broker market power.

[16]The government might be able to help overcome this tradition by requiring brokers to set a fee for services, instead of a percentage commission. The institutional mechanisms that support price discrimination by brokers are not well understood, and an analysis of these institutions, analogous to Reuben Kessel's analysis of price discrimination by doctors, would be valuable. Finally, F. M. Sherer points out that price discrimination may not only reflect a lack of competition, it may also further weaken competition by raising barriers to entry. In the case of real estate, established brokers may attract most of the sellers of expensive houses. New firms then receive the same rate of commission on smaller house values and are therefore at a competitive disadvantage.

[17]To insure that MLSs lead to efficiency gains, the government could also regulate commissions. In most markets, holding the price below the market level lowers output and generates an "excess burden," that is, a loss of consumer's surplus that is not offset by gains elsewhere in society. In the market for broker services, however, the supply curve is downward sloping, so that a lower price implies a higher output and therefore generates an efficiency gain—that is, a negative excess burden. Furthermore, a lower c would induce brokers to cut their search activities. In short, regulation of c could lead to efficiency gains both in the form of extra consumer's surplus and of a decrease in the resources used to produce the same output. The disadvantage of this regulation is that it would cause disequilibrium; the demand for matches would exceed the supply. Despite its potential for enhancing efficiency, therefore, we cannot adequately evaluate commission regulation until we better understand the consequences of this disequilibrium.

should remain a focal point of public policy toward brokers.[18]

IV. Conclusion

The market for real estate broker services is not an ordinary market. The search activities of brokers are inputs for brokers' output, matches between buyers and sellers of housing. However, the market supply curve for matches may be downward sloping because a higher commission discourages sellers from listing with brokers and thereby decreases brokers' ability to make matches. The supply curve also may not reflect brokers' decisions about search; to some degree, broker search activities simply divide matches among brokers and are therefore not a productive use of society's resources. The creation of an MLS, which lowers both commissions and the resources devoted to search, increases the efficiency of the market for broker services. But even with an MLS, the government may want to intervene in this market to lower search activity still further, to lower commissions, or to insure access to the MLS.

These conclusions about public policy should be interpreted with care. In the first place, several important features of the market for real estate broker services are not adequately considered in my model, including the investment aspect of search for sellers, the link between the market for broker services and the housing market, and the importance to market outcomes of variation in broker characteristics. Second, my model has not been tested. The policy analysis in this paper is incomplete without empirical support for the share equations and search equations on which it is based.

Nevertheless, this paper suggests that the welfare gains from government intervention in the market for real estate broker services could be substantial. I hope that this suggestion leads to further investigation of the issues raised here.

[18]For a legal and economic analysis of specific requirements for MLS membership, see my report with Doolittle.

TABLE 1—NOTATION

N_L, N_B	Numbers of sellers of housing (i.e., listings) and of buyers of housing in the system
N_R	Number of real estate brokers
N_V	Average number of brokers visited by a buyer
P_L, P_B	Probabilities that a broker will attract a random listing and a random buyer
P_M	Probability that a random buyer will find a match with a given broker
S_L, S_B	Levels of broker search for listings and buyers
r_L, r_B	Prices of search for listings and buyers
T_B, t_B	Showing costs per buyer and per listing
c	Rate of commission
V	Average house value
M	Expected number of matches for a single broker
H	Number of listings that enter the system during a time period
δ	Probability that a random buyer will match with a random listing
σ	Closing costs for the sale of a house
ρ	Proportions of sellers who list with brokers
α_L, α_B	Proportions of sellers and of buyers who choose a broker on the basis of current-period information
β	Proportion of the commission in an MLS transaction that goes to the broker with the buyer

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Agency, Earnings Profiles, Productivity, and Hours Restrictions

By EDWARD P. LAZEAR*

Economists have concerned themselves with the relationship between a worker's wage rate and his productivity for many years now. The controversy extends back to the early debates on "marginalism" and attempts to demonstrate that variations in wage rates across workers do not correspond to variations in their productivity. The industrial relations literature is replete with examples of empirical analyses along these lines. Theoretical discussions of the separation between wage rates and productivity are copious as well, suggesting that competition breaks down in the labor market context.

This paper argues that it is optimal to construct age-earnings profiles which pay workers less than the value of marginal products (*VMP*) when they are young and more than the value of marginal products when they are old.

The basic point is that even in the absence of on-the-job training or skill acquisition, upward-sloping age-earnings profiles are prevalent. This payment scheme raises workers' utility at the firm's zero-profit equilibrium above that generated by a profile which pays a worker his spot *VMP* at each point in time. This results because holding out payments until late in the individual's lifetime alters the worker's incentives to reduce his effort on the job. As the result, the wage performs two functions. First, it induces workers to supply hours to the labor market, and second, it determines the productivity of each hour spent working. In order to achieve efficiency on the hours and effort margins, hours restrictions are included in wage contracts.[1] This yields a number of implications, some of which are identical to earlier models of age-earnings profiles and others of which differ from those models.

The major points are:

First, wages grow with experience, even if productivity does not. Senior workers receive high salaries, not because they are so much more productive than junior workers, but because paying them higher wages produces appropriate work incentives for them and for their more junior coworkers.

Second, as a result of this separation between wages and spot marginal product, the labor supply decision is distorted. Therefore, efficient employment contracts have hours requirements and restrictions.

Third, a temporary separation is an extreme form of apparent deviation between desired and actual number of hours worked. It is argued below that temporary separations bring about an efficient allocation of time. Allowing workers to choose the number of hours worked at each point in time is inferior and results in inefficiencies.

Fourth, piece rate and self-employed workers will have flatter and more variable wage rates over the lifetime than will time-rate workers.

I. A Model

Since workers are agents of the owner of the firm, it is not automatic that the interests of workers and owners coincide. Workers, for example, prefer to exert less effort per

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[1]The approach is similar to that used in the "agency" literature. A few recent papers on this subject and its relationship to earnings are Armen Alchian and Harold Demsetz, Michael Jensen and William Meckling, Stephen Ross, E. Prescott and R. Townsend, G. Calvo and S. Wellisz, Gary Becker and George Stigler, Robert Barro, Eugene Fama, and W. White.

unit of time worked if their compensation remains unaltered by this effort reduction. Employers, on the other hand, prefer that workers perform at a higher level of effort in order to increase productivity per dollar of wage payment. Sometimes it is efficient to allow the worker to shirk and to pay him less as the result. This occurs when the gains to the worker exceed the cost to the firm of allowing this type of malfeasant behavior. In other instances, however, both workers and firms prefer that the worker does not shirk. Wages in equilibrium will be sufficiently higher so that workers prefer the high-wage/high-effort package to the low-wage/low-effort package. In such a case, it is necessary to construct a compensation scheme that induces the worker to behave optimally. The worker must be paid in a way which brings his interests as agent into harmony with the employer's interests as principal. In the model presented below, it will be shown that an upward-sloping age-earnings profile performs such a task. Even in the absence of any on-the-job training or investment in human capital, it pays to enter into long-term wage-employment relationships which pay workers wage rates less than their *VMP* when they are junior, and more than their *VMP* when they are senior employees.

Let us start by assuming that capital markets are perfect and there is complete information. Under these circumstances, a worker is indifferent between a wage path which offers him his spot wage at each point in time, illustrated by the curve $V(t)$ in Figure 1, and one which pays less than his marginal product initially and more than his marginal product at the end of his working career so long as the present value of the two streams is the same. $W(t)$ in Figure 1 is constructed so that, given the market rate of interest, the present value of the path $W(t)$ from zero to T is equal to the present value of the path $V(t)$ from zero to T. If $\tilde{W}(t)$ is the reservation wage profile, then the optimal date of contract termination is T.[2] Note

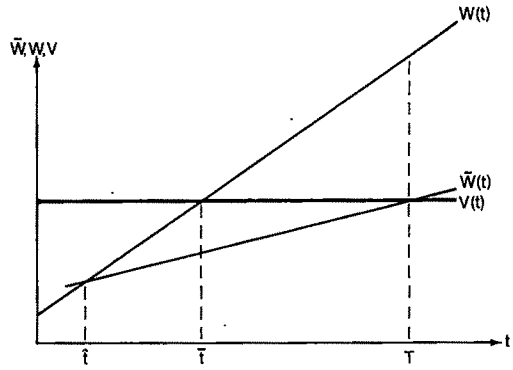

FIGURE 1

that T is the efficient date of retirement; that is, it is the date at which the value of a worker's time used outside this firm exceeds the value of his time used inside the firm. It is therefore the socially efficient point of contract termination.

If other things are equal, workers are indifferent between the two paths. Other things are not equal, however. If receiving one's contracted salary is contingent upon a given performance level at each point in time t, then the costs to the worker associated with shirking are higher given path $W(t)$ than given path $V(t)$. If, at the extreme, shirking results in immediate dismissal, then the larger is the amount of earnings paid at the end of the worklife, the greater would be the cost associated with a given amount of shirking.

Firms may also deviate from the contract. The most obvious form of deviation manifests itself as unanticipated termination of the worker's labor contract before time T. For example, in a world where no information passes from old workers to new workers, it is optimal for the firm to terminate all

[2]This result is used in my (1979 b) article in order to generate mandatory retirement. At T, the wage rate is greater than the individual's reservation wage and the value of his marginal product. Although T is the socially efficient point of retirement, the individual facing a wage path $W(t)$ would not voluntarily retire at that point if given the option. Therefore, the contract must state T as an explicit date of termination. There is no cost to this in an *ex ante* sense because both streams, $W(t)$ and $V(t)$ through T, yield the same present value. Note also that $\tilde{W}<W$ for $t<\hat{t}$ in Figure 1 does not imply that the worker chooses leisure. Since $V(t)>\tilde{W}(t)$ it is efficient for him to work and since enjoying high wages later in life can be made contingent upon his working now, he will agree to work even though $\tilde{W}<W$.

workers at time $\bar{t}$. It is unlikely, however, that contract violations are costless. To the extent that new workers use the firm's history as an indicator of future honesty, a cost is associated with any violation.[3] By altering the shape of the wage profile, the incentives for firm defaults are also altered. Under certain circumstances, a flatter wage profile, that is, one in which a smaller amount of earnings are withheld until late in the worker's life, will result in less dishonesty by firms.

Steeper profiles increase worker effort while flatter profiles will tend to make firms more honest. It seems reasonable, then, to suppose that there will be some optimal profile which minimizes total offenses and therefore maximizes workers' lifetime earnings subject to a zero-profit constraint. Let us proceed more formally.

Let $W(t)$ represent the worker's wage rate at each point in time t. Let $V(t)$ reflect his marginal product at time t if he works at "full" effort. If $\tilde{f}(t)$ is the probability of worker cheating at time t, then $\tilde{f}(t)$ will depend upon the shape of $W(t)$. Suppose that each worker is endowed with a $\theta(t)$, the value of which is known to the worker, but not necessarily known to the firm. Let $\theta(t) \sim f[\theta(t)]$. The term θ is the value (in current dollars) that the worker receives from shirking, reflecting the leisure value of working at a lower effort level. Then $\tilde{f}(t)$ is derived as follows.

Let $\tilde{W}(t)$ be the worker's reservation wage at time t. Let $\tilde{g}(t)$ be the probability that the firm defaults on the contract by terminating the worker at $t<T$. The worker shirks at t if the return $\theta(t)$ exceeds the cost to the worker of shirking. Assume for simplicity that the costs of detection are zero and that the worker is caught and dismissed if he shirks. (This is shown to be an efficient rule below. Replacing this with the assumption that the detection is not certain is trivial. It alters no results, but adds notation.) The cost to the worker of shirking at t is the difference between what he earns at his current firm, $W(t)$, and what he can earn elsewhere (or the value of his leisure if this is higher), $\tilde{W}(t)$. The worker shirks at some point t in his worklife if

$$(1)\quad \theta(t) > \Bigg[e^{rt} \int_t^T \Big\{ W(\tau) - \tilde{W}(\tau) - \big(\tilde{f}(\tau) + \tilde{g}(\tau)\big) \times \Big[e^{r\tau} \int_\tau^T \big(W(\delta) - \tilde{W}(\delta)\big) e^{-r\delta} d\delta \Big] + \tilde{f}(\tau)\theta(\tau) \Big\} e^{-r\tau} d\tau \Bigg] \text{ for any } t$$

Defining the right-hand side of (1) as $R(t)$, the optimal time of shirking is $\underline{t}$ such that $e^{-r\underline{t}}[\theta(\underline{t}) - R(\underline{t})] > e^{-rt}[\theta(t) - R(t)] \forall t \neq \underline{t}$. Thus $R(t)$ consists of the difference between what the worker can earn at his present firm and what he can earn elsewhere ($e^{rt}\int_t^T [W(t) - \tilde{W}(t)] e^{-r\tau} d\tau$), plus his return to shirking ($e^{rt}\int_t^T (\tilde{f}(t)\theta(t) e^{-r\tau} d\tau$) minus the probability that firm or worker initiated separation occurs in the future times the loss if that occurs

$$e^{rt} \int_t^T \big(\tilde{f}(\tau) + \tilde{g}(\tau)\big) \Big[e^{r\tau} \int_\tau^T \big(W(\delta) - \tilde{W}(\delta)\big) e^{-r\delta} d\delta \Big] e^{-r\tau} \delta\tau$$

$R(t)$ is the *ex post* rent that the employee receives by staying with the firm. In terms of Figure 2, $R(t^*)$ is roughly the present value of area *AECD*. *Ex post* rent will vary over the contract period, depending upon the difference between the $W(t)$ and $\tilde{W}(t)$ paths, their rates of convergence and the discount rate.

Since $\tilde{W}(t)$, $\theta(t)$, and r are exogenous, specifying the $W(t)$ path defines $R(t)$. Assume for simplicity, that $\underline{t}$, the optimal time of shirking does not vary across workers. (The value of shirking, $e^{-r\underline{t}}[\theta(\underline{t}) - R(\underline{t})]$, does vary across workers since θ varies across workers.) Since $\theta \sim f(\theta)$ across workers the

[3] This is the notion that reputation capital is affected by performance. This is analyzed in the context of product quality by Benjamin Klein et al.

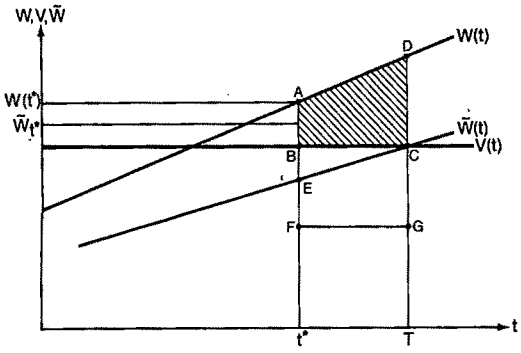

FIGURE 2

probability that a worker shirks at time t is

$$(2)\qquad f(t)=\begin{cases} F[R(\underline{t})] & \text{for } t=\underline{t} \\ 0 & \text{otherwise,} \end{cases}$$

$$\text{where}\qquad F[R(\underline{t})]\equiv\int_{R(\underline{t})}^{\infty} f(\theta(\underline{t}))d\theta(\underline{t})$$

Therefore the greater is $R(\underline{t})$, the less likely is shirking to occur.

The firm's decision to default on the worker's contract can be modeled similarly. Let $\mu(t)\sim g[\mu(t)]$ be the cost to the firm of early default. This cost may reflect the increased difficulty of attracting workers next period, the cost of strikes which result, or other costs associated with morale problems. The firm defaults if for some t,

$$(3)\qquad \mu(t)<e^{rt}\int_t^T\Big\{W(\tau)-V(\tau)-\big(\tilde{f}(\tau)+\tilde{g}(\tau)\big)e^{r\tau}\int_\tau^T[W(\delta)-V(\delta)]e^{-r\delta}d\delta+\tilde{f}(\tau)C(\tau)\Big\}e^{-r\tau}d\tau$$

where $C(t)$ is the cost that the firm suffers in loss of output when the worker shirks. Defining the right-hand side of (3) as $D(t)$, the optimal time of firm default is $\bar{t}$ such that $e^{-r\bar{t}}[D(\bar{t})-\mu(\bar{t})]>e^{-rt}[D(t)-\mu(t)]\forall t\neq\bar{t}$. Thus $D(t)$ consists of the difference between what the worker is paid and what he is worth, $e^{rt}\int_t^T W(\tau)-V(\tau)e^{-r\tau}d\tau$, minus the probability of separation in the future times what is saved if a separation occurs,

$$e^{rt}\int_t^T\big(\tilde{f}(\tau)+\tilde{g}(\tau)\big)e^{rt}\int_\tau^T\big(W(\delta)-V(\delta)\big)e^{-r\delta}d\delta$$

plus the probability that the worker shirks times the direct cost imposed on the firm if that happens, $e^{rt}\int_t^T\tilde{f}(\tau)C(\tau)e^{-r\tau}d\tau$. Given (3), a $W(t)$ path defines $D(t)$ so the probability of firm default at time t is

$$(4)\qquad g(t)=\begin{cases} G[D(\bar{t})] & \text{for } t=\bar{t} \\ 0 & \text{otherwise} \end{cases}$$

$$\text{where}\quad G[D(\bar{t})]\equiv\int_{-\infty}^{D(\bar{t})}g[\mu(t)]d\mu(t)$$

In terms of Figure 2, $D(t^*)$ is roughly the present value of area $ABCD$. As $D(t)$ increases $R(t)$ tends to increase. This encourages firm default, but discourages worker shirking. (Incidentally, the term "default" is appropriate since the firm essentially is borrowing from the worker by paying him less than VMP when he is young and repaying him by paying more than VMP when old.)

The competitive firm must offer a path $W(t)$ which maximizes the worker's expected wealth subject to the constraint that the expected present value of lifetime marginal product equals the expected value of wages paid out. So the problem is

$$(5)\qquad \underset{W(t)}{Max}\int_0^T\Big\{W(t)-e^{rt}\big(\tilde{f}(t)+\tilde{g}(t)\big)\times\int_t^T\big(W(\tau)-\tilde{W}(\tau)\big)e^{-r\tau}d\tau+\tilde{f}(t)\theta_t(t)\Big\}e^{-rt}dt$$

where $\theta_t(t)$ is the value of $\theta(t)$ for the marginal worker who shirks at time t and by equation (1), $\theta_t(t)=R(t)$.

The constraints are first, that honest firms pay out a wage stream, the expected value of which equals the expected value of lifetime marginal product:

$$\text{(6a)}\quad \int_0^T \Big\{ V(t) - e^{rt}\tilde{f}(t)\int_t^T V(\tau)e^{-r\tau}d\tau - \tilde{f}(t)C(t)\Big\}e^{-rt}dt - \xi = \int_0^T \Big\{ W(t) - e^{rt}\tilde{f}(t)\int_t^T W(\tau)e^{-r\tau}d\tau\Big\}e^{-rt}dt$$

where ξ is hiring cost.[4] Second, the optimal contract length or retirement date T should be chosen efficiently so that at T expected VMP equals the alternative use of time. So select T such that

$$\text{(6b)}\quad V(T) - \tilde{f}(T)[C(T) - \theta_T(T)] = \tilde{W}(T)$$

The problem can now be solved. Substituting (6a) into (5) and rearranging yields

$$\text{(7)}\quad \underset{W(t)}{Max} \int_0^T \Big\{ V(t) + e^{rt}\tilde{f}(t)\int_t^T [\tilde{W}(\tau) - V(\tau)]e^{-r\tau}d\tau - \tilde{f}(t)[C(t) - \theta_t(t)] - e^{rt}(\tilde{g}(t))\int_t^T (W(\tau) - \tilde{W}(\tau))e^{-r\tau}d\tau\Big\} \times e^{-rt}dt - \xi$$

subject to

$$V(T) - \tilde{f}(T)[C(T) - \theta_T(T)] = \tilde{W}(T)$$

Since $V(t)$ and ξ are exogenous, maximization of (7) is the same as minimization of

$$\text{(8)}\quad \underset{W(t)}{Min} \int_0^T \Big\{ e^{rt}\tilde{g}(t)\int_t^T [W(\tau) - \tilde{W}(\tau)]e^{-r\tau}d\tau - e^{rt}\tilde{f}(t)\int_t^T [\tilde{W}(\tau) - V(\tau)]e^{-r\tau}d\tau + \tilde{f}(t)[C(t) - \theta_T(t)]\Big\}e^{-rt}dt,$$

subject to (6b).

First, consider the simplest world. Let us suppose that workers have perfect information about a firm's history and know, therefore, whether or not the firm has adopted an honest strategy in the past. If the firm has defaulted in the past, and we assume that $\mu(t)$ does not vary with chronological time, it will do so in the future. As a result, a once dishonest firm is always dishonest. Any contract that it offers is dominated by that of the honest firm. The reason is that in order to induce a worker to accept a long-term contract in the dishonest firm, a flatter $W(t)$ path must be offered (to reduce the firm's incentive to default). But if this is done, the worker's incentive to shirk rises, which causes lower worker productivity.

If we assume that $\max[\theta] < C(t)\ \forall t$ so that $[C(t) - \theta]$ is positive, then shirking associated with the dishonest firm's contract lowers the expected present value of lifetime wealth. (If $C(t) < \theta$, it is efficient to permit the worker to shirk.) The honest firm, on the other hand, can offer a contract which results in less worker shirking. Workers prefer this. Therefore, all dishonest firms vanish. As a result, $\tilde{g}(t) = 0\ \forall t$ in equilibrium.

If $\tilde{g}(t) = 0$, however, the solution to (8) becomes obvious. Wealth is maximized when $\tilde{f}(t) = 0\ \forall t$ (again, because $C - \theta_t > 0$). The path that sets $\tilde{f}(t) = 0\ \forall t$ in general is not unique. Consider a simple case where all workers have $\theta(t) = \bar{\theta}\ \forall t$. Here, any $W(t)$ path which provides that workers are "owed" more than $\bar{\theta}$ in present value terms at all t induces zero shirking.

Figure 3 illustrates some possible wage paths. One path is ABP. Here the worker receives a constant amount less than his VMP

[4] Dishonest firms are not required to earn zero profits. If they are endowed with a low cost of default, they earn rent as the result. Any firm which offers to pay an amount greater than the left-hand side of (6a) immediately identifies itself as dishonest and therefore draws no workers.

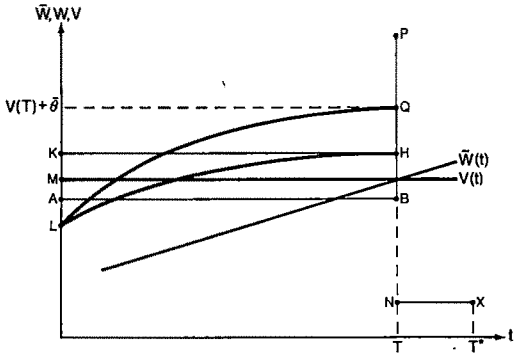

FIGURE 3

over his lifetime, but receives a large lump sum at T to set present values of payment and marginal products equal. There is no worker shirking because $R(t)$ is always greater than $\bar{\theta}$; it never pays to shirk. Another possibility is $LKHQ$. This is the Becker-Stigler solution where the worker posts a "bond" equal to LM, is paid interest on it (KM), and gets back the principal at T ($HQ=LM$). A third possibility is the more conventional $LHNX$. Here the worker is paid less than his VMP initially, more at T, and receives a pension equal to NX. As long as the present value of remaining rent exceeds $\bar{\theta}$ and the present value of lifetime payments equals expected lifetime VMP, this is an optimal path.

The important point is that the optimal paths are upward sloping; $W(T)>W(0)$, even though there is no on-the-job training and no rising VMP schedule. It is optimal to select a profile such that wages are low initially and high later, even in the absence of any experience effect on productivity. Yet, the failure of the spot wage to equal the spot VMP is not a failure of the competitive labor market. On the contrary, it insures higher wealth for the relevant labor force.

In a world which has perfect capital markets, all profiles which yield the same present value are equal. As these assumptions are relaxed below, some changes will result, but the point remains throughout: The link between the spot wage and spot marginal product may be broken even in a fully competitive labor market with risk neutral workers.

II. Determinacy of the Optimum Wage Contract

In the preceding discussion, constraints on the shape of the optimal profile were imposed, but no unique solution could be found. In this section, uniqueness of the optimal path is briefly discussed. The discussion follows three avenues. First, firm default is considered. Second, borrowing constraints are discussed. Third, the effect of taxes is examined.

A. *Firm Defaults*

The case of perfect information has been analyzed above. The only equilibrium is one with complete honesty by firms. However, if information about the firm's default history is less than perfect, the distribution of default costs, ($g[\mu(t)]$), may well be such that it pays some firms to terminate workers early.[5] Under these circumstances, it is no longer optimal to set the worker shirking probability, $\tilde{f}(t)$, equal to zero for all t. The solution in general has $\tilde{f}(t)>0$ and $\tilde{g}(t)>0$ for some t. Since endweighting the profile tends to increase firm default, the profile will tend to be less endweighted than it will be in the case of perfect information. Additionally, since $\tilde{f}(t)>0$ in general, the length of the contract period will tend to be shorter.[6] Finally, since an increase in $R(t)$ can, in general, only be brought about by a decrease in $D(t)$, there is a tradeoff between firm defaults though premature termination and worker shirking which yields a unique solution for the $W(t)$ path. The path has the feature that it is upward sloping and tends to have a pension provision (payment beyond T without work) associated with it.

[5]It is not trivial to generate conditions under which this is so. What is necessary for a stable equilibrium, however, is that $\mu(t)$ is an increasing function of $D(t)$ where $\partial\mu(t)/\partial D(t)<1$ and that $\mu(t)>0$ for some firms even if $D(t)=0$. This says that the larger the gain to the firm from cheating, the larger are the costs borne next period. Without $\mu(t)>0$ and $\partial\mu(t)/\partial D(t)<1$ either all firms will default or raising $D(t)$ will not deter defaults.

[6]Robert Hall uses the notion of optimal contract duration to derive implications for unemployment. This may provide one rationalization for his assumption. Leif Danziger also examines the determination of optimal contract duration.

To see this, consider the general solution to (8). The Euler equation corresponding to (8) is not very useful because neither $\tilde{f}(t)$ nor $\tilde{g}(t)$ is a differential function of $W(t)$. From (1)–(4) it is clear that changes in $W(t)$ change $\underline{t}$ and $\bar{t}$ which makes the nature of the solution discrete.

It is helpful, therefore, to consider two cases. Consider first the case where $r=0$, and θ is constant over time, but varies across individuals. The optimal path can take one of four basic shapes shown in Figure 4: *ABCD*, *EFG*, *HBCK*, or *LFM* (or can be some hybrid of them). Paths *HBCK* and *LFM* can be ruled out immediately. Any firms for which the distribution of $\mu(t)$ requires the optimal paths to be downward sloping goes out of business. The reason is that paying a wage less than *VMP* at the end of life is only viable if there is slavery. (Otherwise workers quit when $W(t)<\tilde{W}(t)$.) Multiple crossing of V by $W(t)$ is ruled out because arguments which apply to *EFG* below will also apply to these paths. The comparison must then be between *ABCD* and *EFG*.

With *ABCD*, $D(t)$ is the same and equal to segment $\overline{CD}$ for all $0<t<T$ (see equation (3)). So $D(t)=\overline{CD}$ and firms will save hiring costs if they default only at T. The firms defaulting at T are those with $\mu(T)<\overline{CD}$.

$R(t)$, however, varies over time since $\tilde{W}(t)$ varies (see equation (1)). $R(t)$ is maximized at $t=T$. So all workers who shirk do so at T (and forego $\overline{CD}$). The shirking workers are those with $\theta(T)>\overline{CD}$.

Now consider *EFG*. Path $W(t)$ is drawn such that the area of triangle *FGC* equals $\overline{CD}$. Consider $D(t)$: $D(t)$ reaches a maximum at $t=t_1$ and then declines until $D(T)=0$. So all firm defaults occur at t_1. The firms that default are those that have $\mu<\overline{CD}$, so exactly the same firms that defaulted with *ABCD* default with *EFG*, but they will do so at t_1 rather than at T. For workers, $R(t)$ declines throughout and so $R(t)=R(T)$ and $t=T$. But $R(T)$ with *EFG* is in general smaller than $R(T)$ with *ABCD* because the area of *FGH* equals the length of $\overline{CD}$: that is, the worker has already received some of what is owed him before T on *EFG* but not so on *ABCD*. Therefore there is more worker shirking with *EFG* than with *ABCD*. But since the

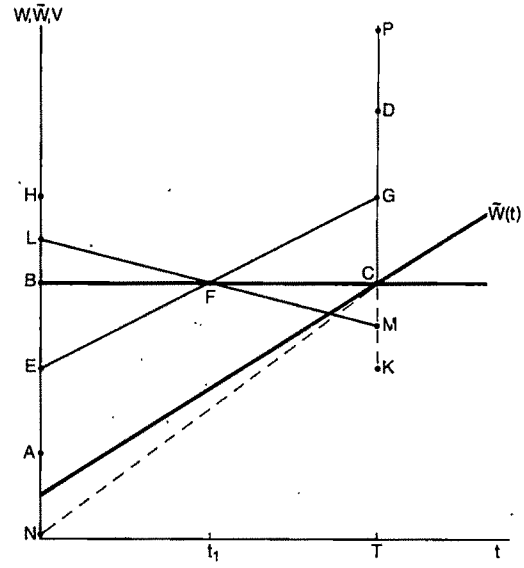

FIGURE 4

amount of firm default is the same in both cases, *ABCD* dominates.

Given that the optimal profile shape is determined, it is a relatively simple matter to solve for the optimal sizes of $R(T)$ and $D(T)$. Since $\tilde{f}(t)=\tilde{g}(t)=0 \quad \forall t\neq T$, $\int_T^T(V(\tau)-\tilde{W}(\tau))e^{-r\tau}d\tau=0$, $R(T)=D(T)=W(T)-\tilde{W}(T)$ (i.e., the worker's potential loss at T is $D(T)=W(T)-V(T)$), and $\theta_T(T)=R(T)$, (8) becomes

$$(9)\quad \underset{R(T)}{Min}\, G[R(T)]R(T) + F[R(T)][C(T)-R(T)]$$

Differentiating and setting the first derivative equal to zero yields

$$(10)\quad G[R(T)]+R(T)G'[R(T)]-F[R(T)] + F'[R(T)][C(T)-R(T)]=0$$

$$\text{or}\quad G[R(T)]+R(T)g[R(T)]-F[R(T)] - f[R(T)][C(T)-R(T)]=0$$

Equation (10) determines the optimal $R(T)$ so that the optimal path is *ABCD* with $\overline{CD}=R(T)$. The spirit of (10) is to select $R(T)$ so

as to trade off a dollar loss in worker wealth from worker shirking against a dollar loss in worker wealth through firm default.

Compare this solution to the earlier one with no firm default. There, $\tilde{f}(t)=0\ \forall t$. Here, in general, $\tilde{f}(T)>0$. In addition, $R(T)$ is smaller when there is endogenous firm cheating than when firm cheating is exogenous. So profiles are less endweighted with endogenous firm cheating. Finally, when firm cheating is endogenous, $\tilde{f}(T)>0$, so the optimal length of the contract will be shorter, by equation (6b).

Let us briefly consider another case. If $\mu(t)$ and $\theta(t)$ are not constant over time then the optimal paths have different shapes. Suppose, for example, that $\mu'(t)<0$ and $\theta'(t)<0$. Then the optimal path will have the shape shown by *NCP* in Figure 4. Since firms face the highest cost of default at low values of t and workers face the highest value of shirking at low values of t, $D(t)$ is relatively high when $\mu(t)$ is high (at low t's). Since $\theta(t)$ is highest for low t's, $R(t)$ is highest for low t's. The profile *NCP* gives this result. Here the optimal profile is upward sloping throughout.

All the paths discussed have one thing in common: The worker (and firm) is indifferent between a spike at T and a pension from T until death which has the same present expected value. Yet pensions are common and lump sum payments are not. The preference for pensions can be explained in a number of ways. First, if workers' time of death were uncertain and they were risk averse, purchase of a pension annuity would be preferred. The second argument is more compelling. Even if firms and workers can obtain the same before-tax return on their dollars, after-tax returns are larger for firms under many circumstances. Therefore, investing in pension funds rather than taking a lump sum payment may offer higher take-home income.

B. *Borrowing Constraints and Taxes*

The assumption that borrowing and lending can be undertaken at the market rate of interest is now relaxed. Like endogenous firm defaults, imperfect borrowing also yields a unique solution for the $W(t)$ path which, in general, is smooth and upward sloping. Without providing a great deal of justification, there are conditions under which it may be sensible to relax the assumption.[7] If workers have utility functions which are time separable and concave in income, then the optimal $W(t)$ path will remain upward sloping, even if all borrowing is prohibited, but will tend to be somewhat flatter than they are when no borrowing constraints are imposed. The intuition is straightforward. Steeper profiles reduce shirking and increase the level of wealth. At the same time, however, a steeper profile yields the worker a consumption time path which is less to his liking. Therefore, workers will trade off some wealth for a better time pattern of payments. Additionally, this yields positive worker shirking even if firms never default, a somewhat shorter contract period, and a unique upward-sloping $W(t)$ path.

A progressive income tax has the same effect on the profile as does a borrowing constraint. A borrowing constraint transforms income into utility along a concave schedule whereas a progressive income tax transforms gross income into net income (and then utility) along a concave schedule. Thus, the results are identical to those above. The profile will tend to be flatter (since more endweighting trades off less shirking against higher taxes); there will be positive worker shirking, a shorter contract period, and a unique upward-sloping age-earnings profile.

III. Additional Considerations

A. *Unanticipated Events, Contract Rigidity, and Severance Pay*

Complete certainty has been assumed so far. This implies that the *VMP* profile $V(t)$ and the reservation wage profile $\tilde{W}(t)$ are

[7]The details are worked out in an earlier draft. To give an example, if the worker has no wealth other than his wage income, the ability of the worker to quit his job to consume leisure (which the bank cannot tax) will affect the willingness of the bank to lend to the worker. This is unrelated to the worker's ability to "shirk" on the firm. Even if output, conditional upon working, were deterministic so that no shirking could occur, the worker has the same option to consume leisure. Therefore, any model which allows for maximization of utility over time is subject to this potentially important criticism.

known and nonstochastic at time zero. We now wish to relax that assumption and to consider the implications of uncertainty for efficiency and determination of the optimal wage profile.

Consider Figure 2. Suppose that at some time t^*, the worker receives an unanticipated wage offer from another firm equal to $\tilde{W}_{t^*}$. It is socially efficient for the worker to switch firms at that point since the value of his time in the new firm exceeds the value of his time in the old firm. However, given his wage rate of $W(t^*)$, other things equal he would prefer to remain with his current firm where his labor is less valuable. At time t^*, the firm still owes the worker the present value of trapezoid *ABCD*. If the worker could recoup that value at point t^* as severance pay, then he would choose to leave the firm and to work at the alternative job. Employers break even so the worker and the firm behave efficiently, if severance pay is permitted.

The argument is symmetric. If $V(t)$ were to fall to some unanticipated level below $\tilde{W}(t^*)$, say to $\overline{FG}$ in Figure 2, then there is some scheme which will induce the worker to leave efficiently. Let the firm offer the worker epsilon above the present value of *AECD* to leave. The worker prefers this since he earns $\int_{t^*}^{T} W(t)e^{-rt}dt = \int_{t^*}^{T} \tilde{W}(t)e^{-rt}dt$ + the present value of *AECD* if he stays, but he gets a payment of the present value of *AECD* + epsilon if he leaves and then earns $\int_{t^*}^{T} \tilde{W}(t)e^{-rt}dt$ elsewhere. The latter dominates the former by epsilon. The firm benefits as well. If the worker stays, the *ex post* loss is only the present value of *AECD* plus epsilon rather than *AFGD*. The advantage that this scheme has over employer initiated termination without severance pay at t^* is that the employer has no incentive to offer severance pay *AECD* plus epsilon unless $V(t)$ has truly fallen. Employer initiated termination without severance pay creates information problems.

Note also that the efficient contract contains a clause which states that the worker may leave at any t and will be compensated $\int_{t}^{T} [W(t) - V(t)]e^{-rt}dt$ as severance pay. In addition, firms have the option to dismiss workers at $t < T$ as long as they pay the worker $\int_{t}^{T} [W(t) - \tilde{W}(t)]e^{-rt}dt$. So severance pay is larger when the firm initiates the separation (for reasons other than worker shirking).

This also implies that workers who are older than t in Figure 1 will be willing to accept a new job at a wage rate lower than their current wage even if all characteristics of the two jobs are the same and there is no hope of wage increases on the second. If the new wage lies between $V(t)$ and $W(t)$, the worker will leave and accept his severance pay. Public workers often retire from the public sector early to accept another at a lower wage. This "double dipping" phenomenon may well be an efficient arrangement where pension benefits serve as severance pay.[8]

B. *Piece Rates as an Alternative Compensation Scheme*

The contract discussed has the provision that workers who shirk are dismissed. An alternative is to pay the worker a lower salary for that period. This is what Fama refers to as "*ex post* settling up" or what amounts to paying a piece rate, an amount which depends directly upon the individual's output in the preceding time interval.[9] If output were costlessly measurable, *ex post* settling up yields an equally efficient solution. However, if output were costlessly observed, the principal agent distinction loses most of its meaning. Piece-rate workers are, in a relevant sense, self-employed. If it were cheaper to observe that shirking is positive than it was

[8]Severance pay may take the form of early pensions which exceed the actuarially fair value of the pension if the worker were to continue through normal retirement. Both R. Burkhauser and Alan Blinder et al. find that workers who retire early enjoy actuarially larger pension benefits.

[9]Piece rates are not easily distinguishable from time rates. To the extent that a worker's hourly wage in the future depends upon his output now, he receives "piece rate" compensation in some sense. The major distinguishing characteristic is that under piece rate compensation, as the term is used in this paper, a worker is compensated at the end of a period for work done during that period. This is not merely a point of semantics since the endgame problem is an essential part of the discussion. See my article with Sherwin Rosen for more on this point.

to determine the precise amount of shirking, the contract which dismissed all shirkers would dominate. The widespread existence of rules which require the dismissal of shirkers is testimony to measurement cost differences. (A worker caught sleeping on the job is usually dismissed rather than docked pay for the hours slept. Embezzlers find themselves without jobs when caught rather than with a smaller paycheck for the month.)

There is, however, a cost to using dismissal over the more continuous piece-rate scheme. Suppose output $V(t)$ were stochastic consisting of an effort component $E(t)$, and a luck component $u(t)$, so $V(t)=E(t)+u(t)$ and that only $V(t)$ could be measured. Under the dismissal scenario, a worker who experiences a bad draw is dismissed, even if his effort level is satisfactory. If there are any costs associated with job changes, this policy results in a loss of wealth to workers. Thus, in occupations where $\sigma^2_{u(t)}$ is large, paying a piece rate may well dominate, even if it is more costly to determine the exact level of shirking than it is to know that it is positive. The prediction is that piece rates will be found not only in occupations where output is measured cheaply, but also in occupations which have a large luck component associated with a given individual's variation in output over time. Salesmen fit this case well.[10]

Once one allows for a choice of compensation schemes, it is natural to consider endogenous monitoring. There is no reason to assume that the probability of detection is one or that detection is not chosen simultaneously with the shape and type of wage path. That much more difficult problem is left unsolved.

IV. Some Implications

A. *The Relationship between the Spot Wage and Marginal Product*

The upward-sloping age-earnings profile is an efficient compensation scheme which does not equalize spot wage rate and spot marginal product. A direct implication of this analysis is that a worker's earnings should rise more steeply than his marginal productivity over the lifetime.[11] This is consistent with often heard complaints that more senior workers earn considerably more than their juniors, but that these salary differences far overstate productivity differences. Senior workers are paid a high wage not because they are productive at that point in time, but rather because paying high wages to older workers induces young workers to perform at the optimal level of effort in hopes of growing old in that firm.

A somewhat trivial extension of this point is that the aggregate income distribution will have positive variance and, in fact, positive skew even if all individuals have the same ability and lifetime marginal product. Young workers are paid less than their marginal products. Old workers receive this amount plus interest which adds variance and skew to the distribution of income.

B. *Hours Constraints and Layoffs*

Consider the age-earnings profile illustrated in Figure 1. Wages are less than *VMP* when the worker is young and greater than *VMP* when the worker is old. Consider a time t such that $t<\bar{t}$. The worker's marginal

[10]Self-sorting as discussed by Joanne Salop and Steven Salop, and Rosen, insures that individuals who face large job changing costs or the least risk-averse workers who can trade a higher $\sigma^2_{u(t)}$ for a larger $E(t)$ select piece rate firms. This is one way by which the adverse effects of having a risk-averse manager in a risk-neutral firm can be mitigated. This problem, which has been considered by Donald Heckerman, can be solved by fixed "prize" compensation scheme. Here workers are paid W_1 if $V(t)>\bar{V}$ and W_2 if $V(t)<\bar{V}$. Under these circumstances, risk-averse worker do not necessarily avoid variance. My article with Rosen demonstrates that such a scheme is often efficient.

[11]Some evidence on this point is offered by Gene Dalton and Paul Thompson, and more recently, by James Medoff and K. Abraham. By examining data from two major American corporations, Medoff and Abraham find that wage rates grow with experience at a more rapid rate than does productivity when measured by the subjective evaluation of the supervisor. Merton Miller and Myron Scholes also provide evidence on this point. By using data on executive compensation they find that the deferred nature of the compensation package is often tax disadvantageous and argue that the reason for this form of compensation may be incentive related.

product is given by $V(t)$, while his wage rate $W(t)$ is less than that amount. If the worker were permitted to select the number of hours that he wished to work at that point in time, he would select hours consistent with the wage rate $W(t)$ rather than with the social value of time $V(t)$. A positively sloped supply curve of labor implies that the worker would choose to work too few hours at times earlier than $\bar{t}$ and too many hours at times later than $\bar{t}$. (In fact, an extreme case of the desire to work too many hours after $\bar{t}$ results in mandatory retirement. See my 1979b article.) The steep age-earnings profile $W(t)$ results in an inefficient labor allocation over the lifetime. An efficient contract must constrain the worker to work the efficient number of hours at each point in his worklife. As a result, workers actually prefer to enter into long-term contracts which constrain them to work hours which they know will deviate from their hours choice at the spot wage. The reason is that the lifetime wealth associated with a contract which allows them to choose hours freely is sufficiently low to offset utility gains from flexible hours.[12] The proof of this proposition follows.

Consider a two-period world. Suppose, for simplicity, that the hours supply function is the same in both periods. Let VMP be constant across hours (again for simplicity) so that H^* is the efficient number of hours worked in periods 1 and 2 as shown in Figure 5. Let W_1^* and W_2^* be the wage rates which solve the optimization problem in (8) subject to constraint that total wages paid equal VMP (or that $(W_1^*+W_2^*)H^*=2VH^*$ if $r=0$). Hours are constrained to be H^* in both periods. The question is, "does there exist another wage vector $[W_1, W_2]$ which allows the worker to choose his hours of work, which yields the worker higher utility and which is viable in that payouts to workers do not exceed VMP?"

[12]The deviation between desired and actual hours is discussed and analyzed by Orley Ashenfelter and J. Abowd and Ashenfelter. It should be mentioned that a two-part wage could bring about the same allocation of resources as single wage with hours constraint. These schemes imply the same age-earnings profile, however. Hall and Lilien also present a model where the workers give the hours decision over to employers as part of a second best bargaining process.

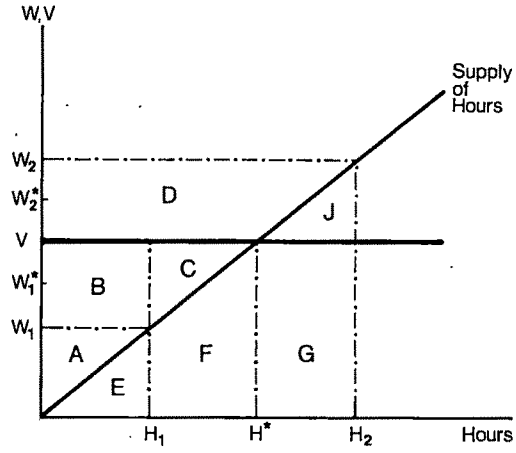

FIGURE 5

Suppose that there were such a wage vector. If it is truly utility increasing then the rent to the worker with $[W_1, W_2]$ and hours $[H_1, H_2]$ must exceed that generated by the constrained hours contract. In order for this to hold, the rent from the flexible hours contract

$$R_f \equiv A+(A+B+C+D)$$

where $A,\ldots,J$ are defined as the areas in Figure 5, must exceed the rent from the constrained hours contract. However, total wages paid under the constrained contract are $2(A+B+C+E+F)$. Total value of leisure foregone is $2(E+F)$. So rent from the constrained contract is

$$\begin{aligned} R_C &= 2(A+B+C+E+F)-2(E+F) \\ &= 2(A+B+C) \end{aligned}$$

Assume that such a flexible hours contract exists. Then

$$A+(A+B+C+D)>2(A+B+C)$$

or $D>B+C$. For the flexible hours contract to be viable, it must also be true that wages paid out do not exceed total VMP or

$$\begin{aligned} &(A+E)+(A+B+C+D+E+F+G+J) \\ &\leqslant (A+E+B)+(A+B+E+C+F+G+) \end{aligned}$$

or that $D+J \leqslant B$. This implies that $D<B$ and therefore that $D<B+C$. But this contradicts the assumption that $D>B+C$. This

completes the proof that no flexible hours contract exists which both makes workers better off than the constrained hours contract and does not result in losses for the firm.

An implication is that young workers should complain that they are forced to work too many hours and old workers should similarly complain that they are not permitted to work enough. Complaints about mandatory retirement are extreme manifestations of this phenomenon. A corollary is that old workers are more likely to accept overtime hours than are young workers.

It is straightforward to extend the discussion of hours constraints over the lifetime to temporary separations. Involuntary separations are puzzling because they suggest that the spot wage does not adjust with *VMP*. Once it is recognized, however, that wage rates are not only able to allocate hours efficiently, but may also affect the output per hour, it is no longer surprising that the spot wage is not permitted to reflect spot *VMP* to insure an efficient hours allocation.

Consider the case of anticipated variations in labor demand which, for example, result from seasonal effects. Some workers who are "laid off" might be willing to work at the going wage or at their previous one, but are refused employment. Recall that the wage of employed workers also affect the effort level over the entire year so that bringing wages into line with a low *VMP* results in lower effort and output during the entire contract term.

An efficient contract is illustrated in Figure 6. Consider two workers: A is employed only during peak season and B is employed throughout the year. Suppose that A's and B's reservation wage functions are given by $\tilde{W}_A(t)$ and $\tilde{W}_B(t)$, respectively, in Figure 6. Periods 0 to t_0 and t_1 to t_2 are high seasons, t_0 to t_1 is low season. It is efficient for A to use his time in its alternative use between t_0 and t_1, while B should continue to work at the present firm throughout. The optimal wage path for A will not be the same as that for B, but one point is clear: Although offering $W_A(t)=W_B(t)=V(t)$ will induce efficiency in hours supplied, it will necessarily result in too much shirking. A superior path for A is $W_A(t)$ since it increases effort. But

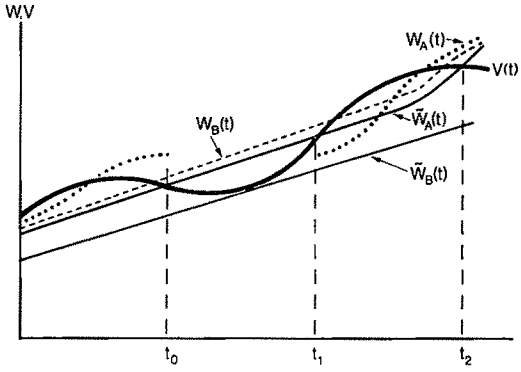

FIGURE 6

this path requires that A is unemployed between t_0 and t_1. Worker B continues to work during this period. There is no real cost to this seasonal layoff. *Ex ante*, A prefers $W_A(t)$ to path which pays spot *VMP* at each point since the latter induces more shirking and results in lower net *VMP* and lower wealth. Yet if A were asked whether he would like to work at the market wage (either his own wage at t_0 or $W_B(t)$ between t_0 and t_1), he would answer affirmatively, even though $W_A(t)$ with separations is efficient and preferred.[13]

"A" type workers are those with the most elastic labor supply whose alternative use of time is closest to their value at work. This suggests that the young workers (whose alternative may be school) are the first to be laid off in low season. As such, layoff by

[13]The notion that long-term contracts which imply layoffs during cyclical downturns dominate spot *VMP* contracts has been analyzed. See, for example, Costas Azariadis, Martin Baily, Herschel Grossman, Dale Mortensen, and James Brown. A major difference between this analysis and those is that risk neutrality is sufficient, whereas in previous analyses, risk aversion is the primary engine of "involuntary separation." In this paper, separations come about because the wage rate is a tool which is reserved to equilibrate the quality-of-hours margin, so that the quantity of hours is necessarily set by explicit means. There is no reason to expect that workers would be paid during layoff periods. If the risk aversion story were correct, one would expect that workers on layoff would receive earnings related to the difference between the wage rate and the value of leisure. This would provide more complete income smoothing. Workers with different values of leisure self-sort across firms which offer different combinations of wages when employed and wages when on layoff, all consistent, of course, with total compensation equal to expected marginal product.

reverse seniority can be viewed as part of the efficient contract.

This section can be summarized. The wage rate affects two variables. It determines the amount of effort per hour worked and influences the desire to supply hours to the market. Since there is but one degree of freedom, it is superior to allow the wage rate to adjust the effort margin and to use quantity constraints to obtain efficiency on the hours margin. This is because it is cheaper to monitor and directly regulate the quantity of hours worked than it is to monitor and regulate the amount of effort supplied. Note also that piece-rate or self-employed workers, whose wages equal marginal product, do not experience involuntary layoffs even though cyclical variations in their employment may be as pronounced. Since their wages reflect the actual spot value of their output, they will voluntarily slow down or take a vacation during off-peak periods. Also, since piece-rate workers earn what they produce, there will be fewer disciplinary dismissals of piece-rate workers so permanent separation rates should be lower for piece-rate employees.

C. *Other Implications*

1. *Human Capital.* The upward-sloping age-earnings profiles generated by the model presented in this paper is difficult to distinguish from an upward sloping age-earnings profile generated by the standard human capital theory. Many of the implications are the same.

First, ability constant, both models suggest that steeper age-earnings profiles are coupled with lower starting wages. In a human capital story, this is because workers trade off earnings now in order to purchase human capital which increases their productivity later in life. In the incentives scenario discussed in this paper, workers prefer that firms pay lower wages initially and higher wages later so that incentives to shirk are reduced.

Second, separation of older workers from firms results in a larger decrease in wages than does separation of younger workers from firms in both models. In the human capital model this is the result of specific on-the-job training or specific human capital which the worker has acquired over his worklife. In the incentives scenario, it is the result of an age-earnings profile which pays workers less than the *VMP* when they are young and more than the *VMP* when they are old.

Related to that is the implication that there are fewer worker-firm separations when workers are old than when workers are young. Again, the human capital model yields this as the result of the accumulation of specific on-the-job training. The incentives scheme gives this as an implication when severance pay arrangements are imperfect or taxed. This occurs because the deviation between wages and marginal products increases over the worker's lifetime.

A job switch is often followed by an initial drop in wages with a succeeding increase in the rate of wage growth. Human capital theory can explain this as a reinvestment period during which the individual acquires the new specific capital. The incentives scenario suggests that this is the period during which the worker is putting up collateral.

An important, but overlooked point, is that investment in firm-specific human capital also requires hours constraints and severance pay as part of an optimal contract. Since any sharing of costs and benefits of the firm-specific human capital results in a wage which is below the worker's true marginal product, trained workers voluntarily choose too few hours. The problem is most severe when the firm bears most of the costs and reaps most of the benefits of the specific capital, and hours constraints should be most prevalent under these circumstances.

There are some implications which do differ across models. In the human capital framework, there is no reason to believe that piece-rate workers should have flatter age-earnings profiles than time rate workers. That is, there is no obvious reason why skill acquisition should be less profitable in occupations which pay workers piece rates than in occupations which pay workers time rates. On the other hand, the incentives scheme has the implication that piece rates are used in occupations where the uncontrollable variance in output and therefore income is relatively high. When piece rates are used, the resulting age-earnings profile is flat because piece rates are a substitute for up-

ward-sloping age-earnings profiles. Thus, salesmen should have less steeply rising profiles than should management employees. As a corollary, individuals who work in large firms should have steeper age-earnings profiles than those who work in small owner-operated firms where monitoring costs are low. Self-employed workers should also have flatter profiles.

Of course, the most fundamental difference between the human capital scenario and the incentives scheme is that in the human capital model, earnings and productivity are positively correlated over the life cycle. In the simplest form of the incentives scheme with no skill acquisition or depreciation, the correlation between productivity and wages over the life cycle is zero.

One final point. Some empirical phenomena do not square well with the human capital theory. The discrete nature of the age-earnings profile is difficult to reconcile in terms of standard human capital models. For example, on a given day, all the vice presidents of a corporation may be earning $75,000 per year. The following day, one is promoted to president and earns $250,000 a year. It is difficult to rationalize this jump in earnings as reflecting a jump in human capital. On the other hand, if incentive effects are produced by this wage increase, it can be rationalized easily.

2. *Unions.* The upward-sloping age-earnings profile is the outcome of contract negotiations because of an asymmetry. The worker is finite lived whereas the firm is assumed to operate with a longer time horizon. A labor union is also likely to have a longer relationship with an employer than is an individual worker. If the union can act as an intermediary and, through peer pressure or more direct supervision, can monitor and regulate the work force at a lower cost than can the firm the union may be a substitute for an upward-sloping age-earnings profile. If a worker shirks, the union is taxed in succeeding rounds of negotiations. In turn, the union taxes the actual offender. If this were so, age-earnings profiles would be flatter, but higher, for union workers.[14] Alternatively, the union may be relatively more efficient at monitoring firms. If this were the case, then union workers would have steeper and higher profiles than their nonunion counterparts.

[14]James Heckman and G. Neumann and my 1979a article provide evidence that this is in fact the case.

V. Conclusion

This paper suggests that by using a more steeply rising age-earnings profile, a worker's incentive to shirk is reduced. As the result, workers are better off and their lifetime wealth levels are increased. Age-earnings profiles are upward sloping, even if a worker's productivity does not vary over his life cycle. Setting wages equal to spot marginal product at all points in time is dominated by a contract which selects a steeply rising age-earnings profile and uses quantity restrictions on hours worked to obtain an efficient allocation of time to and effort on the job.

TABLE 1—DEFINITION OF VARIABLES

$W(t)$	observed wage path
$V(t)$	full-effort productivity profile
T	date of retirement
$\tilde{W}(t)$	reservation wage profile
$\tilde{f}(t)$	probability of worker shirking at t
$\tilde{g}(t)$	probability of firm default at t
$\theta, \theta(t)$	utility value of shirking
$f(\theta)$	density of θ across workers
$\mu, \mu(t)$	cost to firm of firm initiated default on worker's contract
$g(\mu)$	density of μ across firms
$C(t)$	cost imposed on firm by worker's shirking
$F(\theta_0)$	$\int_{\theta_0}^{\infty} f(\theta)d\theta$
$G(\mu_0)$	$\int_{-\infty}^{\mu_0} g(\mu)d\mu$
$\underline{t}$	optimal shirking time for worker
$\bar{t}$	optimal default time for firm
$\theta_t(t)$	θ value for marginal worker who shirks
ξ	hiring cost
$R(t)$	present value of difference between earnings at firm and alternative use of time from t to T
$D(t)$	present value of difference between wages paid to worker and his value to the firm from t to T

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Income-Leisure Tradeoffs of Animal Workers

By RAYMOND C. BATTALIO, LEONARD GREEN, AND JOHN H. KAGEL*

Results of recent empirical and theoretical research have shown the applicability of consumer demand theory in describing and predicting choices of nonhuman consumers (see A. Covich, D. Rapport and J. Turner, Battalio et al., Kagel et al., 1975, 1980). Commodities used in these studies have been largely limited to different kinds of edibles: food grains, water, and sweet tasting (preferred) fluids. A natural extension of the commodity choice model is to consider leisure as a good.

This paper presents results of experiments showing that nonhuman workers (pigeons) are willing to trade off income for leisure if the price is right. More specifically our results show that the Slutsky-substitution effect is positive for (exactly) compensated wage decreases, and that leisure is a normal good at all points in the choice space. In addition to demonstrating the pervasiveness of income-leisure tradeoffs, the experiments show strong regularities in the size of the substitution and income effects at varying wage rates; with increases in real wages both income and substitution effects get smaller, but the substitution term decreases more rapidly than the income term resulting in a backward bending labor supply curve at higher wages.

The plan of the paper is as follows. In Section I we characterize the procedures employed in the laboratory for studying labor supply, and summarize well-established characteristics of this behavior as it is relevant to the present experiments. Sections II and III describe the hypotheses tested and the experimental procedures employed in the tests. Results of the experiments are given in Section IV. Some of the implications of these results are discussed in a brief concluding section.

Space considerations do not permit a detailed discussion of the reasons why economists should take seriously the investigation of economic theories using nonhuman subjects (see Kagel and Battalio for this argument). For the more skeptical reader we simply note that if one defines economics as "...the study of the allocation of scarce resources among unlimited and competing uses" (Albert Rees, 1968, p. 472), then animal psychologists, ecologists and biologists have been involved in studying economic behavior for some time now (Rapport and Turner; Jack Hirschleifer; H. Rachlin). It is but a small step to take the technologies of these related disciplines and apply them to behavior of interest to economists, for example labor supply behavior. At a minimum, such studies expand considerably the scope for comparative economic analysis. At a maximum they provide a laboratory for identifying, testing, and better understanding general laws of economic behavior. Use of this laboratory is predicated on the *fact* that behavior as well as structure vary continuously across species, and that principles of economic behavior would be unique among behavioral principles if they did not apply, with some variation, of course, to the behavior of nonhumans.

I. Procedures for Studying Labor Supply in the Laboratory

In studying response patterns under ratio schedules of reinforcement, operant psychologists have established an operational basis for studying labor supply in the laboratory. Under these procedures value is induced on a job task through making performance of

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the task a necessary prerequisite to obtaining access to preferred activities. Commonly used job tasks consist of key pecking and treadle running for pigeons, lever pressing and wheel running for rats.[1] Preferred activities typically consist of eating or drinking for food- or water-deprived animals, although a substantially wider variety of reinforcers have been used.

Under a ratio schedule of reinforcement, the job task must be performed a prescribed number of times (N), on average, to obtain a prescribed amount (A) of the preferred commodity. This experimentally induced constraint on behavior can be written as

$$C=wR; \quad w=A/N \tag{1}$$

where R is the total number of times the job task is performed and C is total consumption of the preferred commodity. Equation (1) characterizes job-related earnings under a piecework pay schedule in a barter economy where w is the real wage rate, R is the total number of pieces produced, and C is total income or consumption derived from working.[2]

The job task is available for a limited period of time each day. This imposes a second constraint on behavior:

$$T=H+L \tag{2}$$

where H is time spent working, L is leisure time (time not working), and T is total time available.[3] Since the amount of time taken to complete a given key peck or lever press can, for all practical purposes, be treated as a constant, a,

$$H=aR \tag{3}$$

Substituting (3) into (2) and rearranging

$$L=T-aR \tag{4}$$

Also rewriting (1) to allow for the possibility of free or unearned income (F)

$$C=wR+F \tag{5}$$

equations (4) and (5) specify the constraints on time and consumption. These correspond in all essential respects to the constraints commonly postulated in economics for workers making short-run decisions concerning how much time they work and income they earn.[4]

While it is one thing to argue that rats and pigeons can be placed under constraints similar to those specified in textbook formulations of consumption-leisure tradeoffs, it is quite another thing to postulate that they maximize, or act as if they maximize, a well-behaved utility function of the sort

$$U=U(C, L) \tag{6}$$

Nevertheless examination of the relevant empirical data suggests that this is the case. We summarize some of the most important findings below.

A. *Results From Other Studies*

Labor supply schedules obtained under the procedures described above are either bitonic, forward rising at low wages, becoming vertical and bending back at higher wage rates, or negatively sloped throughout. Although Rees notes that "Unfortunately, there is no empirical basis for the forward sloping portion of the (bitonic) curve" (1977, p. 12), data from a number of different species un-

[1]These job tasks represent behaviors that subjects are readily capable of performing. For some tasks, wheel running in rats for example, work levels would be positive even in the absence of reinforcement contingent on performing the task.

[2]As early as 1953, B. F. Skinner suggested that ratio schedules used to study behavior in the laboratory had all the essential characteristics of a piecework job and could be employed to study work-related activities. To our knowledge, no one has pursued this analogy until recently.

[3]In many psychology experiments this second constraint is not imposed. Rather sessions are terminated after a predetermined number of reinforcements or payoffs (R/N) have been obtained.

[4]Of course, the correspondence established here is but one of many ways to operationalize the theory. We do not claim uniqueness, only that the laboratory operations establish a logically consistent way of operationalizing the theory, and thereby provide a valid basis for investigating it.

der a variety of experimental conditions regularly display this pattern. These include humans and rats pressing levers for access to alcohol, rats pressing levers for food pellets and concentrated sucrose solutions, mice pressing levers for a fortified milk diet, and pigeons pecking a response key for access to food (see our 1979 paper and J. E. R. Staddon for reviews of the literature).[5]

Irrespective of the shape of the labor supply function, demand for income is inversely related to effort price ($1/w$); consumption decreases with increases in effort price. This pattern is found in rats, pigeons, monkeys, and humans working for such items as food, water, saccharin and sucrose solutions, alcoholic beverages and intravenous injections of all sorts of drugs, both addictive and otherwise (see J. A. Hogan and T. J. Roper, and J. Allison for reviews). This inverse relationship holds even though subjects have adequate time to maintain consumption at all but the very lowest wage rates in the shortest time sessions. Thus, hypotheses of target income earning behavior do not do well over the kind of piecework job tasks and with the species employed in these studies. The nearly universal nature of this inverse relationship between income and effort price suggests that in cases where the relationship breaks down, we should look for shifts in preference patterns or undetected changes in experimental conditions to explain the behavior.

Equation (1) implies that labor supply behavior depends upon the ratio of the amount of the preferred commodity received (A) relative to the number of responses required to complete the job task (N), and not on their absolute values. Allison et al. have investigated this proposition with rats lever pressing (holding a lever down) in order to gain access to drinking from a water spout. In one experiment, the ratio of seconds of lever pressing to seconds of drinking varied from 5:5 sec., 10:10 sec. to 20:20 sec. with total session time held constant. The rats spent 17.0, 17.4, and 18.7 percent of the session lever pressing, differences that were not statistically significant. This was replicated in a second experiment in which ratios of pressing to drinking varied from 20:20 sec. to 30:30 sec., and from 10:20 sec. to 20:40 sec., although labor supply varied systematically with differences in the real wage, A/N. These data, and data from other experiments as well, indicate that behavior is relatively insensitive, over a fairly wide range of values, to change in nominal work requirements as long as the real wage (A/N) remains constant.

It is a well-established principle of labor supply that if workers have a choice of two (or more) jobs with no difference in nonpecuniary returns from the jobs, then they will work exclusively on the job with the higher wage rate (see Gary Becker, pp. 166–170, for example). Animals choosing between two similar jobs (say, which of two keys to peck at) providing qualitatively similar kinds of consumption (say, the same kind of grain) essentially face this kind of situation. Experiments reported by R. J. Herrnstein and W. Vaughn provide dramatic evidence that, under these conditions, pigeons indeed maximize, choosing to work exclusively, or almost exclusively, on the job with the higher real wage rate.

In choosing between working to obtain food or eating it from a source of continuously available free food, animals show a near-exclusive preference for obtaining their food freely, provided stimulus change conditions (changing color lights, sounds, etc.) associated with both alternatives are the same. However, in experiments where stimulus change is associated with earned income with no corresponding changes for free food, subjects (including humans) continue to work and often obtain 50 percent or more of total income by working (S. R. Osborne reviews this literature). Thus, pigeons and rats do not work for bread alone; the stimulus changes typically programmed to coincide with food deliveries have the status of "nonpecuniary" sources of income commonly thought to influence labor supply decisions within national economies.

We have presented a picture of work behavior in the laboratory that is in remarkably

[5]In an informal review of some forty different experiments, Staddon notes that about half of the studies yield bitonic labor supply functions.

close accord with prior expectations based on neoclassical economic theory. In doing so, we have not had to suppress untidy results, the picture is a remarkably consistent one. It is this consistency which motivated the tests of the Slutsky-substitution effect reported in the next section. Although the theory allows the labor supply curve to be of any shape, and even permits increases in consumption with increases in effort price (a Giffen good) over portions of the choice space, there is no ambiguity regarding the sign of the Slutsky-substitution effect.

This is not to say that the psychologists who conducted the experiments surveyed support a maximizing model of the type employed here. In fact some of them explicitly reject this approach (see Herrnstein and Vaughan, also Allison et al.). We will return to the question of competing explanations of the data following the consistency tests reported below.

II. Experimental Design

Figure 1 provides a graphical representation of the experimental design. Subjects start out working at wage rate w_1, with the level of free income F_1, set equal to zero (budget line OA). The income-leisure choice bundle, represented by point X, is observed. Subjects are then given a positive level of nonwage income F_2, and wages decreased to w_2 until the quantity of labor supplied reaches its previous level, R_x. Should this point be reached, wages revert to their original level w_1.

The new budget line, $OBXA$, provides an exactly compensated wage rate decrease relative to the original choice point X. Convexity of the indifference curves, or simple consistency of choices in terms of revealed preference theory, requires that the new choice point lie somewhere on the interval BX of the new budget line. Choice point Y illustrates one of many possible consistent choices. The new budget line $OBXA$ involves a Slutsky-compensated wage change, and the interval $R_x - R_y$ measures the magnitude of the Slutsky-substitution effect.

Following establishment of stable choice behavior under the new budget line, free income F_2 is reduced to zero with wage rate

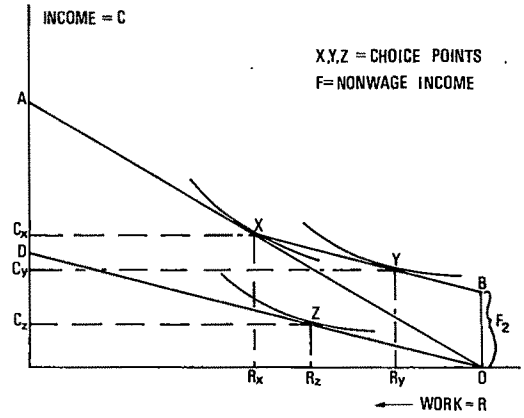

FIGURE 1

w_2 maintained throughout the work period. This new budget line OD is parallel to the BX portion of the compensated wage rate line. In this way we can isolate and directly measure the effect of nonwage income F_2 on labor supply.

The sequence of budget line manipulations shown in Figure 1 was repeated at a number of different wage rates. In this way we can test for consistency of choices at different wages and observe the shape of the labor supply schedule and the associated demand for income schedule. Given this design we can also decompose changes in labor supplied $(R_x - R_z)$ into their component Slutsky-substitution effects and income effects.

$$(7) \qquad \underset{\text{change in labor supplied}}{(R_x - R_z)} \equiv \underset{\text{Slutsky-substitution effect}}{(R_x - R_y)} + \underset{\text{income effect}}{(R_y - R_z)}$$

This enables us to identify changes in the magnitude of the income and substitution effect along different segments of the labor supply schedule. For example, we can determine whether the backward-bending portion of the labor supply schedule is due to a decreasing substitution effect, an increasing income effect or some combination of the two.

III. Method

Subjects were male White Carneaux pigeons with no previous experimental history. The job task consisted of pecking a response key for access to a food hopper containing mixed pigeon grains. Wages were always changed by altering the average number of pecks per payoff, with access time to the hopper fixed at 3 seconds. Pecking requirements varied from as much as 400 pecks per payoff to as little as 12.5 pecks.[6] The wage rate is measured in terms of an index number valued at 100 for conditions requiring 100 pecks per payoff.

Free income also came in the form of 3 second periods of access to the food hopper. These free food deliveries were programmed to arrive throughout the entire experimental period whether the bird was pecking or not; their delivery was strictly time dependent.[7] The number of free food deliveries for a particular compensated wage change was determined on the basis of mean earnings from the last five days of the relevant baseline period; in terms of Figure 1, F_2 was determined on the basis of mean consumption during the last five days under budget line OA.

Compensated wage changes consisted of delivery of free income with a compensating adjustment in the response requirement for earning income. For example, if, under baseline conditions, the subject was pecking 50 times per payoff (wage index=200), then a compensated wage change might consist of setting free income to one-half its baseline value and adjusting the work requirement to 100 pecks per payoff (wage index=100).[8] Thus, a bird responding the same number of times under the free income condition as under the baseline condition would obtain the same number of food presentations. However, half of the food would be delivered freely throughout the session while the other half would be obtained as a result of working. Furthermore, reduced work output during this condition would always result in a decrease in consumption.

Experimental conditions were maintained for a minimum of 30 sessions per condition. Conditions were terminated when successive three-day periods showed no trend over the last nine days of the condition. Data reported are mean values computed over the last five days of each condition. The order of experimental conditions was varied across subjects. Conditions were occasionally replicated to test for stability of preferences.[9]

Experimental sessions were run once a day, seven days a week, in a sound insulated pigeon test chamber. Sessions lasted 40 minutes, not counting the time during which the food hopper was presented. Water and grit were continuously available in the pigeons' home cages. The pigeons were maintained at 80 percent of their free feeding weights throughout the experiment. This effectively eliminates changes in body weight as a confounding factor in the results reported.

IV. Experimental Results

A total of twenty-two different Slutsky-compensated wage changes were imple-

[6]Under all experimental conditions, the number of pecks required per payoff (N) was determined by a random ratio schedule. Under a random ratio schedule, payoffs (access to the food hopper) occur randomly with a predetermined average value; with a random ratio 50 schedule ($RR50$) the bird would obtain 3 seconds access to the food hopper following every 50 pecks on average. The probability density function was binominal. We used a random rather than a fixed (nonstochastic) ratio requirement because 1) subjects adjust more rapidly to changes in conditions under the random schedule, and 2) random schedules tend to promote higher response rates at low wage rates thereby providing a more demanding test of the theory.

[7]Free food was delivered according to a random schedule also, a variable time (VT) schedule. The probability density function was exponential. The availability of free food was signaled by the food hopper being elevated and lighted in the same fashion as food deliveries obtained by working. Previous work with pigeons established that they can detect the difference between free and earned sources of income delivered in this fashion (Rachlin and Baum).

[8]However, as noted in Section III, once pecks exceeded the average baseline value, work requirements reverted to the baseline level (wage index=200 for the example in the text).

[9]The full data set underlying the analysis along with additional procedural details are reported in our forthcoming article.

mented across six different subjects. In nineteen cases, the sign of the substitution effect was consistent with the predictions of the theory; compensated wage decreases resulted in reduced labor supply as hungry birds gave up food to spend more time in nonwork activities. The probability of this happening by chance is less than .001, assuming an equal probability of obtaining a correct as compared to an incorrect sign for the substitution effect. Further, in eighteen of the nineteen consistent cases t-tests show the differences in mean amounts of labor supplied to be statistically significant at the 1 percent level or better (significant at the 10 percent level in the remaining case). Replications of some of the baseline budget lines showed that in cases where the substitution effect had the correct sign behavior was reversible; preferences were sufficiently stable that comparing labor supply under the compensated wage rate condition with either the original choice point or the replicated choice point shows a statistically significant reduction in labor supply of approximately the same magnitude in either case.

Of the three inconsistent cases, one failed to pass a significance test at conventional levels of acceptance. In a second case, replication of the baseline wage rate condition showed a large increase in labor supply, suggesting that a shift in preference structures, or some undetected change in experimental conditions, might have been responsible for the inconsistency. Repeating the compensated wage change using the new baseline choice point resulted in a significant substitution effect with the correct sign. For the third inconsistency, elimination of the free income resulted in a statistically significant increase in income relative to the baseline wage rate. This was the only violation of the law of demand for income (the inverse relationship between effort price and income) found in the experiment, suggesting that baseline preferences had shifted in this case also.

All three inconsistencies occurred starting from the budget line with the highest real wage rate ($w=800$). Analysis of the full set of experimental results shows regularities in terms of income and substitution effects that suggest that both inconsistent choices and more highly variable preferences may be expected at these higher wage rates. In the rest of this section we document these regularities, returning to the inconsistencies following this analysis.

Slutsky-compensated wage changes were implemented at four different wage rates for four of the subjects. In each case, the level of free income was set at 50 percent of the previous period's earnings and wages were halved. In these cases the percentage change in the variables determining the size of the substitution effect were held constant across experimental conditions, thereby facilitating direct comparisons of the size of the substitution effect at the different wage rates. The results of these manipulations are shown in Table 1, where average responses over the last five days of the initial wage rate period and under the compensated wage rate period are given for each subject. Also shown are absolute changes in the number of responses and their percentage change relative to the baseline period, both for individual subjects and the group.

These substitution effects have a number of interesting properties. While the size of the substitution effect differs a good deal among different individuals, these differences are fairly consistent across different wage rates. Thus, subjects 47 and 49 show percentage reductions in labor supply about twice as large as that for subjects 48 and 50, with the single exception of subject 49 at the highest wage rate. Apparently different birds have different preferences with respect to tradeoffs between income and leisure. These differences in substitution effects, which do not correlate well with differences in baseline work levels (labor supply with no free income), suggest that no simple rule of thumb will account very well for the behavior, and that what we are observing is not a result of simple genetic imprinting.[10]

[10]The correlation coefficients (with associated t-statistics in brackets) for the relationship between baseline labor supply and percentage change in work due to the Slutsky-compensated wage changes are −.18 (.26), −.74 (1.57), −.29 (.43) and .66 (1.23) going from the

TABLE 1—SLUTSKY-COMPENSATED CHANGES IN LABOR SUPPLY

		Wage Rates								Correlation Coefficient
		100	50+ ½free	200	100+ ½free	400	200+ ½free	800	400+ ½free	
Subject 47	Work[d]	4680	44	4286	197	3657	1486	4540	2855	-.91 (3.19)[a]
	Change[d]	4636[c]		4089[c]		2171[c]		1685[c]		
	Percent Change[e]	99		95		59		37		-.97 (5.23)[b]
Subject 48	Work[d]	5839	2889	6908	4249	6648	4173	4144	3686	-.97 (5.41)[b]
	Change[d]	2950[c]		2659[c]		2475[c]		458[a]		
	Percent Change[e]	51		38		37		11		-.97 (5.50)[b]
Subject 49	Work	6162	328	5290	1065	4905	1097	3932	4027	-.98 (6.94)[b]
	Change	5834[c]		4225[c]		3808[c]		-95		
	Percent Change	95		80		78		-2		-.96 (4.77)[b]
Subject 50	Work	5343	2914	5375	3596	4756	3877	4846[f]	4008	-.84 (2.23)
	Change	2429[c]		1779[c]		879[c]		838[c]		
	Percent Change	45		33		18		17		-.84 (2.23)
Average Values	Change in Work	3962 (5.07)[b]		3188 (5.42)[b]		2333 (3.88)[a]		721.5 (1.93)		
	Percent Change in Work	72.5 (5.09)[b]		61.5 (4.01)[a]		48.0 (3.68)[a]		15.8 (1.94)		

Note: *t*-statistics are shown in parentheses.
[a]Significant at 10 percent level.
[b]Significant at 5 percent level.
[c]Significant at 1 percent level.
[d]Mean for the last 5 days under each condition.
[e]Percent change$=(w_0-w_1/w_0)\times 100$ where w_0 and w_1 measure work during the baseline and compensated wage change periods respectively.
[f]Subject 50 was originally inconsistent under this condition.

While the size of the substitution effect does not correlate well with baseline labor supply, there is a strong negative correlation with respect to wage rates for all subjects. This negative correlation holds for both the absolute size and percentage change in labor supplied. Since the percentage change in wage rates is the same amount at each point, this implies that both the absolute size and elasticity of the (Slutsky) substitution effect decrease with increases in real wage rates.

Table 2 shows the effect of free income on labor supply at each of the wage rates for which data are available. In all cases the addition of free income, holding wage rates constant, results in a reduction in total labor supplied; leisure (not working) is a normal

lowest to the highest wage rate. Similarly, small *t*-statistics are found in comparing baseline labor supply with absolute changes in work, although the power of these tests are low due to the sample size.

TABLE 2—EFFECTS OF FREE INCOME ON LABOR SUPPLIED

Wage Rates	Work[c]	Free Income[c]	Change in Work[c]	Percent Change in Work[d]
Subject 47				
50+free	44	24.0	−1777[b]	−98
50	1821			
100+free	197	43.0	−4483[b]	−96
100	4680			
200+free	1486	73.0	−2800[b]	−65
200	4286			
400+free	2856	179.4	−801[b]	−22
400	3657			
Subject 48				
50+free	2889	29.0	−2030[b]	−41
50	4919			
100+free	4249	69.4	−1590[b]	−27
100	5839			
200+free	4174	133.0	−2734[b]	−40
200	6908			
400+free	3686	166.4	−2962[b]	−45
400	6648			
Subject 49				
50+free	328	31.8	−4751[b]	−94
50	5079			
100+free	1065	53.0	−5097[b]	−83
100	6162			
200+free	1097	95.8	−4193[b]	−79
200	5290			
400+free	4027	167.2	−878[b]	−18
400	4905			
Subject 50				
50+free	2914	27.2	−1619[b]	−36
50	4533			
100+free	3596	54.0	−1747[b]	−33
100	5343			
200+free	3877	95.0	−1498[b]	−28
200	5375			
400+free	4008	193.6	−748[b]	−16
400	4756			

[a]Significant at 5 percent level.
[b]Significant at 1 percent level.
[c]Mean for last five days under each condition.
[d]Percent change $= w_1 - w_0 / w_0 \times 100$ where w_1 and w_0 measure work with and without free, respectively.

good in this environment. Here, too, we find empirical regularities in that for three of the four subjects (47, 49, and 50) the absolute size of these income effects decreases at the higher real wage rates. More striking still is the steady decrease in the percentage change in work as real wages increase, even though the absolute amount of free consumption increases with real wages too.[11] This suggests a strong interaction effect between wage rates and nonwage income in labor supply response, a point we return to shortly.

TABLE 3—LABOR SUPPLY AND DEMAND FOR INCOME

Subject	Wage	Labor Supplied[a]	Income Earned[a]
47	50	1821	9.4
	100	4680	47.2
	200	4286	85.7
	400	3657	145.8
	800	4540	362.9
48	50	4918	25.3
	100	5839	61.7
	200	6908	106.0
	400	6648	196.1
	800	4144	316.2
49	50	5078	24.5
	100	6162	58.1
	200	5290	137.3
	400	4905	266.0
	800	3932	331.2
50	50	4533	22.6
	100	5343	53.7
	200	5375	107.5
	400	4756	190.3
	800	4846	387.0

[a]Mean for last five days under each condition.

Free income also results in an increase in total consumption (free plus earned) holding wage rates constant for 15 of 16 observations. Under the conditions of this experiment consumption is a normal good too.

Table 3 draws together data from Tables 1 and 2 to show labor supply and demand for income schedules with no free income. For all subjects labor supply increases up to wage rate 100–200, after which it tends to bend back on itself, results consistent with data reported from other experiments. The data also rule out explaining the positive substitution effects of Table 1 as a simple response to decreases in wage rates; the wage change part of the Slutsky-compensated changes tends, by itself, to increase labor supply over the backward bending portion of the curve. The data in Table 3 also show demand for income increasing uniformly with increases in real wage rates (decreases in effort price). This provides yet another confirmation of

[11]Free income as a percentage of maximum income earnings is approximately constant, or decreases slightly with increases in real wage rates, hardly enough to account, by itself, for the diminishing impact of free on labor supply.

TABLE 4—EMPIRICAL LABOR SUPPLY FUNCTIONS
(t-Statistics in Parenthesis)

Subject	Independent Variables: *Log* Wage	(Log Wage)^2	*Log* Free Income	*Log* Free Income x *Log* Wage	N	R^2	$D.W.$
47	5.48	−.49	−2.37	.39	12	.91	1.45
	(2.01)[a]	(1.89)[a]	(4.31)[a]	(3.68)[c]			
48	2.34	−.22	−.15	.01	12	.95	2.69
	(6.54)[c]	(6.50)[c]	(1.86)	(.67)			
49	1.89	−.19	−1.72	.26	12	.97	2.70
	(3.35)[b]	(3.27)[b]	(6.84)[c]	(5.00)[c]			
50	.75	−.08	−.37	.06	15	.80	2.01
	(1.73)	(1.83)[a]	(4.34)[c]	(3.60)[c]			

Note: $D.W.$ = Durbin-Watson statistic; N = number of observations.
[a]Significant at the 10 percent level.
[b]Significant at the 5 percent level.
[c]Significant at the 1 percent level.

the law of demand; income changes inversely with changes in effort price. It also rules out simple target income earning hypotheses as potential explanations of the birds' behavior.

To follow up the suggestion from Table 2 that the size of the income effect tends to decrease with increases in wage rates, we fit the following empirical labor supply function to the data

$$(8)\quad \log R = \log a_0 + a_1 \log w + a_2 (\log w)^2 + a_3 \log F + a_4 (\log w \cdot \log F)$$

where the notation is that of Section I. If income effects interact with wage rates as suggested, the sign of the coefficient a_4 should be positive and statistically significant. Further, negative and statistically significant values for a_2, in conjunction with positive values for a_1, would provide formal support for the argument that the labor supply functions are bitonic.

Table 4 shows the results of least squares fits of (8) to the data.[12] Observations consisted of mean values computed over the last five days of each condition, including repeat observation points and compensated wage changes in addition to those reported in Table 1. In all cases, the sign of the interaction term a_4 is positive as suspected, and is statistically significant at the 1 percent level or better in 3 of 4 cases. Further, in four of four cases a_2 is negative in sign and statistically significant at the 10 percent level or better. This in conjunction with the positive sign for a_1 confirms the bitonic shape of the labor supply curve.

While income effects must dominate substitution effects for the labor supply curve to bend back, there are a number of ways this can happen; the substitution effect might get smaller with the income effect growing in size, or both effects might be getting larger with the income effect growing more rapidly, etc. The results of Tables 1 and 2 identify the particular mechanism underlying the backward bending labor supply curves here. Both income and substitution effects get smaller in absolute value as wages increase, but the substitution effect decreases relatively more than the income effect. In other words, the economic variables, wages and nonwage income, have less important influences on behavior as real wages increase. Further, within any experiment there are a number of factors we cannot *completely* control for; for example, changes in temperature, the force required to peck the key, fatigue or minor physical disabilities on the subjects part. Thus, as real wages increase, the control of economic variables on behavior diminishes, while the influence of "other" environmental factors remains constant; experimental control diminishes with an approximately constant level of uncontrolled factors ("noise")

[12]In cases where there was no free income, $\log F$ was set to zero.

in the environment. This tends to promote less stability (lower repeat reliability) of the data at these high rates as well as a higher frequency of inconsistent behavior, both of which were observed in the data (recall the discussion of inconsistent cases at the beginning of this section).

V. Discussion

The results of the present experiments indicate the pervasiveness of income-leisure tradeoffs and the need to account for them in understanding behavior. Hungry pigeons consistently choose to decrease work time in response to Slutsky-compensated wage decreases. They do so in an environment which is designed to promote key pecking (labor supply) since there is little else for the birds to do except preen themselves and walk about. Further, the job task, key pecking, is not awkward or difficult for pigeons to perform but is highly compatible with their evolutionary niche. Substitutability of income and leisure appears to be a fundamental, biologically based, law of behavior.[13]

Although we have used a simple neoclassical theory of labor supply to explain work patterns, this explanation would not be universally accepted by either economists or psychologists. Among economists, Becker's theory of irrational behavior is prominently cited as an alternative to the neoclassical model in the context of consumer demand behavior (see Herbert Simon). Can it be used to explain our results? We think not.

In the irrational behavior model, subjects behave in one of two ways: They are inert, whenever possible consuming exactly what they did in the past, or they are impulsive, simply randomly deciding how to allocate funds between commodities. For the inert case subjects simply do not respond to changes in relative costs as long as they can maintain their initial consumption position. However, since subjects are randomly distributed across the budget line, and data typically consist of average market values, compensated price changes will still result in a correct sign for the Slutsky-substitution effect for the market as a whole (see Becker for details of this argument). For exactly compensated price changes based on individual consumption values, none of the subjects should adjust. Clearly, this is not the case for our data.

In the impulsive choice case, consumers spend a constant proportion of their income on each good. With constant proportionate budget shares Slutsky-compensated price changes result in a correct sign for the substitution effect. A natural translation of this decision rule in the present context would be that subjects spend a constant proportion of their time working,

$$H/T=b \tag{9}$$

where, in accord with our earlier notation, H designates time spent working, T is total time and b is a constant. Substituting (3) into (9) and rearranging

$$R=(b/a)T \tag{10}$$

which, since T is constant, implies a constant amount of labor supply, irrespective of wage rates. Behavior is indistinguishable from subjects having a Cobb-Douglas utility function, as long as nonwage income is zero. One would need to introduce additional rules into the irrational behavior model to account for the effects of nonwage earnings on behavior. Fortunately, we do not have to specify such a rule in order to eliminate this model as a contender since the data from both our experiment (Table 4) and others reported in the literature show labor supply to be far from inelastic. This analysis also rules out the simple Cobb-Douglas utility function as an explanation for the observed behavior.

[13]This is *not* to assert that substitutability of consumption for leisure is under common genetic control in pigeons and humans. Behavioral similarities may result from the fact that both species face similar environmental contingencies for which such substitutability is a survival characteristic, and have independently developed the capability of making such adjustments. This corresponds to biologists distinction between "homologous" sources of similarities, those due to common genetic ancestry, and "analogous" sources, those due to common functions. Biologists face difficult "identification" problems here in determining the basis for any particular behavior.

Leading psychological theories that might be used to explain the data are the matching law (Herrnstein) and conservation theory (Allison et al.). Neither one organizes the data however. First, the matching law implies a positively sloped labor supply curve throughout (Timberlake), which is clearly at odds with the data. Second, conservation theory implies a linear, negatively sloped labor supply curve throughout (Allison et al.). The bitonic shape of the labor supply curve observed here, and in a number of other studies as well, contradicts this.[14]

These past few paragraphs have not exhausted competing explanations of the data. One can extend Becker's irrational behavior framework to generate more complicated labor supply schedules than the ones considered here, while we have far from exhausted the inventory of available psychological models. Specifying and testing between these and other models of labor supply is a story for another time and another place. What we can say is that, at the present time, there are no simple rules of thumb or well-established psychological models capable of organizing the data reported here or elsewhere in the literature. As such we continue to employ the Slutsky-Hicks theory to analyze molar (session value) data, and to organize our inquiries.

While the present experiment concentrated on the effects of changing wage rates on income and substitution effects holding deprivation level (body weight) constant, the procedures employed can be applied to other variables of interest. For example, in another study Green and Green looked at the effects of changing deprivation level on the amount of labor supplied. Operationalizing deprivation level in terms of pigeons' body weight (70 percent as compared to 95 percent of normal weight) they found smaller substitution effects at higher deprivation levels. In other words when birds were at 70 percent of normal body weight they substituted less than when they were maintained at 95 percent of normal weight. These data in conjunction with the present experiment suggest that while low wage rates faced by low-income workers tend to promote larger substitution effects than their high wage counterparts, their relatively higher deprivation level in terms of the available consumption set tends to offset these differences. It will take a 24-hour experiment, in which deprivation level is allowed to covary with wages, in order to determine the net effect of these two competing factors.

Whether the results of these or any other experiments with animals should be considered seriously in terms of understanding human economic behavior, no less be taken into account in reaching public policy recommendations, remains an open question at this time. At a minimum, animals provide a vehicle for empirically investigating and sorting out between competing theoretical explanations at a relatively low cost, uncluttered by extraneous events likely to be encountered with comparable studies in national economic systems. The relevance of such studies is predicated on the fact that there is behavioral as well as physiological continuity across species as students of psychology, biology and a number of other disciplines have recognized for some time now. To argue that our experimental results are not applicable to humans because the latter are much more complex than pigeons or work in substantially more complex environments seems awkward. If a theory does not work for these simple organisms under these simple conditions, how can it possibly work for more complex organisms in a more complex environment?

At a maximum, such theories enable us to investigate issues with potential public policy implications such as factors responsible for the size of income and substitution effects in labor-leisure tradeoffs and the impact of economic variables on the distribution of earnings. *It is an empirical question whether the pigeons' (or rats') leisure interacts with their income in the same way that a person's leisure interacts with that person's income.* We have enough information now to give a partial answer to this question: to the extent we can rely on the available data, the income-leisure tradeoffs of pigeons are in many respects similar to those of humans.

[14]Rachlin et al. compare the merits of a maximization-theory approach with reinforcement theory in describing steady-state behavior.

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Retail Inventory Investment and the Cost of Capital

By F. OWEN IRVINE, JR.*

Theoretically, the level of inventory a firm desires to hold depends on the costs associated with holding the inventory.[1] Yet most studies of inventory investment in recent years have ignored the possible dependence of target inventory levels on inventory carrying costs.[2] Target inventory levels have been postulated to depend solely on future expected sales.[3] This is probably explained by the repeated failure of nearly all earlier empirical studies to find any significant influence of interest rates on inventory investment.[4] For example, Michael Evans in his survey of the aggregate inventory investment literature in 1969 concluded: "Thus in the absence of virtually any theoretical or positive empirical evidence on the role of credit factors influencing inventory investment, we can state that links between the real and monetary sectors, however important they are in other parts of the economy, are of negligible importance here" (p. 214).

The econometrically estimated inventory equations reported in this paper do not support Evans' conclusion. Target aggregate retail inventory levels are shown to depend significantly on variations of a capital cost measure of the Hall-Jorgenson type. The estimated coefficients imply that the increases in interest rates which occurred over 1972–74 reduced target retail inventory levels by 2.3 billion 1973 dollars. Time-series equations explaining the monthly inventory levels

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[1]See the models of T. M. Whitin, Edwin Mills, or my 1980a paper, for example.

[2]Surveys of the literature have been done by Paul McGouldrich, Robert Eisner and Robert Strotz, Michael Lovell (1964), Evans, and J. L. Bridge.

[3]A recent exception being Maurice Levi who reports obtaining the "wrong sign" on the three-month Treasury bill rate when it was included in his estimated equation.

[4]Many earlier studies of inventory investment behavior attempted to find a dependence of target inventory levels on interest costs. Nestor Terleckyj found no statistically significant effect on aggregate inventory levels. Newton Robinson seeking to explain department store inventory levels also found no interest rate effect. The survey paper by McGouldrick summarizes these early studies and others trying to assess the evidence on whether credit conditions and costs influence inventory levels. He also reports that the results of a Federal Reserve Board study, which included interest rates and other measures of credit availability in inventory equations, were disappointing. In the durable manufacturing inventory equation, the interest rate had a negative but statistically insignificant sign while in the distribution sector inventory equation, the interest rate coefficient was positive. Surveying the influence of credit stringency, Lovell (1964) reports that he found incorrect signs on an interest rate variable in regressions explaining deflated durable and nondurable manufacturing inventory levels. In a later paper for the Brookings model with Paul Darling, Lovell reports that he again found perverse positive signs on the interest rate when he included it in manufacturing inventory equations. Darling, in that same paper, however, reports preliminary regressions for the distribution sector which show a negative and statistically significant coefficient on a bank interest rate on short-term loans in the equations for retail trade (less autos) inventory equation. The estimated coefficient on this bank interest rate was insignificant, however, in the equation explaining wholesale trade inventories. Insignificant coefficients were also obtained in separate equations explaining inventories of retail durable goods and retail nondurable goods. Jon Joyce, utilizing firm cross-sectional data, also found a negative but statistically insignificant coefficient on a short term bank interest rate.

Only three studies found a statistically significant negative coefficient on the interest rate. An early study by Albert Ando et al. estimated over the period 1947:3 to 1960:1 found the short-term rate on bank loans to be statistically significant. They estimated the point-of-means elasticity of the target inventory with respect to it to be −0.4. The authors, however, were cautious about their results, because this result was not robust. In two studies, T. C. Liu (1961, 1969) reported a negative statistically significant estimated coefficient on a "real interest rate" which he defined to be the rate on prime commercial paper less the lagged rate of change of the *GNP* deflator.

held by the total retail sector, and the nondurable and durable subsectors were estimated over a 1958–74 sample. The estimated elasticities indicate that the target inventories of durable goods are much more sensitive to variations in financial inventory carrying costs than are the inventories of nondurable goods. The estimated coefficients also show that retail inventories are adjusted quite rapidly to their desired levels; this contrasts with the relatively slow speed of adjustment generally found for manufacturing sector inventories. Although retail inventories have averaged 25.2 percent of total manufacturing and trade inventories since 1959, this sector generally has been neglected by econometric investigations. My survey of the post-World War II literature found only six previous econometric studies of retail inventory behavior and none since 1965 dealing with aggregate U.S. retail sector inventory investment.[5]

The stock-adjustment specification and the variables utilized are discussed in Section I. The estimated equations are presented in Section II along with a table of estimated elasticity values. In Section III, some possible reasons why I obtained a significant capital cost effect are investigated. In Section IV, inventory disequilibrium is examined by comparing actual with target inventory levels historically. The final section consists of a short summary and discussion of some of the implications of these findings.

I. Equation and Variable Specifications

Nearly all econometric studies of inventory investment behavior have employed the "stock-adjustment" model (sometimes called the "flexible accelerator" model). This model hypothesizes 1) that each firm has a desired target level of inventory, and 2) that each firm, finding its actual inventory not equal to its optimum level, attempts only a partial adjustment towards the optimum level within any one period, i.e.,

$$(1)\quad y(t)-y(t-1)=\delta\big(y^d(t)-y(t-1)\big)+\varepsilon(t) \qquad 0<\delta<1$$

where $y(t)$ = actual level of inventories held at beginning of period t
$y^d(t)$ = optimum (target) level of inventories desired to be held at beginning of period t
δ = "reaction" or "speed-of-adjustment" coefficient
$\varepsilon(t)$ = random disturbance term.

Several factors account for the inertia of firms in adjusting their actual inventory levels to their target levels. Among these are the costs of changing the level of inventory held. Expansion of the level of inventories to a new higher target level may involve the cost of setting up new display facilities, building or renting new storerooms, hiring and training extra stockroom personnel, and the inefficiency costs associated with the temporarily crowded conditions until the new storage capacity can be added. Also, depending on the type of good, it can take a considerable amount of time to obtain delivery of the goods ordered; clothes, for example, must be ordered months in advance. Decreasing the level of inventories to a new lower target level also involves delays and costs. Since most suppliers will not take back goods, there is the time it takes to sell off the excess inventory of goods. This rate of sales can generally be speeded up by incurring the additional costs associated with either extra advertising or holding a sale, that is, marking down the excess inventory of goods. Since many of these costs increase with the amount of inventory change attempted per period, that is, the adjustment cost function is convex, firms spread over several periods their adjustment toward their inventory targets. Because all of these costs are dynamic adjustment costs associated with changing the

[5] These previous studies are those by Robinson, Bridge and Clement Wilson, Darling and Lovell (1969), P. K. Trivedi, and my 1976 dissertation. My study, and Lovell's both utilized micro data on individual department store inventories.

amount of inventories held, the partial adjustment model was specified as a function of amount of inventory disequilibrium.[6]

Equation (1) can be rewritten as

$$(2)\quad y(t)=\delta y^d(t)+(1-\delta)y(t-1)+\varepsilon(t)$$

The unobservable optimum inventory level $y^d(t)$ is postulated to depend on the level of expected future sales and inventory carrying costs:

$$(3)\quad y^d(t)=\alpha_0+\alpha_1\hat{S}(t)+\alpha_2 CA\hat{P}C(t)$$

where $\hat{S}(t)$ = expected sales over the appropriate future period where the expectations are held at time t

$CA\hat{P}C(t)$ = expected per unit inventory carrying cost over the future period over which the inventory will be held.

Substituting (3) into the stock adjustment equation (2) we obtain

$$(4)\quad y(t)=(1-\delta)y(t-1)+\delta\alpha_0+\delta\alpha_1\hat{S}(t)+\delta\alpha_2 CA\hat{P}C(t)+\varepsilon(t)$$

A. *Sales Expectations*

To estimate equation (4), data on expected sales in the upcoming period $\hat{S}_t$ are needed. Like most previous researchers, I had no expected sales series available and thus had to utilize a proxy. Most of the structural proxies for expected sales used to date have hypothesized that future expected sales are some function of past sales. The simple naive expectations model which sets expected sales equal to last period's sales, i.e., $\hat{S}(t)=S(t-1)$, has been used in several studies including those by Paul Darling, and J. Lawrence Bridge and Clement Wilson. Others including Robert Ball and P. S. Drake, Newton Robinson, P. K. Trivedi, and Steven Grossman have specified $\hat{S}(t)$ to be a distributed lag over past sales. John Johnston (1961) employed for seasonally unadjusted quarterly data Ferber's law of expectations formation.[7]

$$(5)\quad \hat{S}(t)=S(t-4)+\theta S(t-4)\times\left[\frac{S(t-1)-S(t-5)}{S(t-5)}\right]$$

where $S(t)$ = actual sales in quarter t

θ = a parameter to be estimated

A priori, it is not clear which of these "structural proxies" is a better measure of expected sales. I chose to try alternatively two different proxies.

A sales forecast commonly utilized by retail firms is last year's sales in the same month adjusted by the store's recent sales experience.[8] To generate this type of "retailer proxy forecast" of expected sales, the following formula is utilized:

$$(6)\quad ESDCM(t)=DSALES(t-12)\left[\left(\frac{1}{3}\right)\left[\frac{DSALES(t-1)}{DSALES(t-13)}+\frac{DSALES(t-2)}{DSALES(t-14)}+\frac{DSALES(t-3)}{DSALES(t-15)}\right]\right]$$

[6]For manufacturing firms, George Hay has argued that most of the dynamic adjustment costs are associated with changing the level of production, and therefore, the partial adjustment model should probably be specified in terms of production levels. For retail firms, the level of net purchases (sales plus change in inventories) would be analogous to the production level. However, the majority of adjustment costs for a retail firm seem to be directly a result of changing the level of inventories, not as a result of changing the rate at which orders arrive. Hence, my choice to specify the partial adjustment in terms of $(y^d(t)-y(t-1))$.

[7]See Albert Hirsch and Lovell (pp. 115–21) for a thorough discussion of the use of this by Robert Ferber and others.

[8]Cyert and March (pp. 135–36) report the use of this type of sales forecasting formula by the departments of a department store whose operations they studied in detail. Also, in personal interviews conducted with the managers of over 30 retail stores, I found that this was by far the most commonly utilized forecasting method (see my dissertation, ch. 6). Also Trivedi, in a recent study of aggregate retail inventories in the U.K., found that a formula very similar to (6) forecast well.

TABLE 1—CORRELATIONS BETWEEN MONTHLY CHANGES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total Retail Sector									
(1) Actual sales	1.0								
(2) Current-month forecast by retailer proxy	.94	1.0							
(3) Current-month forecast by ARIMA model	.95	.98	1.0						
Nondurable Goods									
(4) Actual sales	.98			1.0					
(5) Current-month forecast by retailer proxy				.96	1.0				
(6) Current-month forecast by ARIMA model				.98	.98	1.0			
Durable Goods									
(7) Actual sales	.82			.70			1.0		
(8) Current-month forecast by retailer proxy							.78	1.0	
(9) Current-month forecast by ARIMA model							.77	.90	1.0

Note: Column headings are identical to that listed on line with corresponding line number.

where $ESDCM(t)$ = expected deflated sales in the upcoming month t

$DSALES(t)$ = actual deflated sales in month t.

This formula adjusts a linear extrapolation by the amount such a linear extrapolation would have been off over the previous three months. In establishing their target inventories of most nonperishable goods, retail firms generally take into account the sales they expect to make over the next several months. Thus, in addition to $ESDCM(t)$, a forecast of sales expected one-month ahead, $ESD1M(t)$, and a forecast of sales two-months ahead, $ESD2M(t)$, were included in the specification. These latter two measures were calculated by a formula identical to equation (6) except that the first term after the equal sign was replaced by $DSALES(t-11)$ to calculate $ESD1M(t)$ and was replaced by $DSALES(t-10)$ to calculate $ESD2M(t)$. Thus, for example, as of October 1, $ESDCM(t)$ is a measure of sales expected in October, $ESD1M(t)$ is a measure of sales expected in November, and $ESD2M(t)$ is a measure of sales expected in December. For those stores whose inventory planning period is less than three months, we would expect to find the estimated coefficient on $ESD2M(t)$ and perhaps $ESD1M(t)$ to be insignificant. By initially including $ESD1M(t)$ and $ESD2M(t)$ in all the equations as a measure of expected sales in the upcoming period (i.e., for $\hat{S}_t$), we avoid any specification error in absence of knowledge about the actual length of the inventory planning period.

As an alternative to the "retailer proxy forecast" described above, seasonal ARIMA models were fitted to the deflated actual monthly sales series over a 1956–74 range.[9] Then the upcoming month forecast, $AESDCM_i(t)$, the one-month ahead forecast, $AESD1M_i(t)$, and the two-months ahead forecast, $AESD2M_i(t)$, were generated for use as a proxy for expected sales. These alternative ARIMA forecasts are more effi-

[9]For total retail sales, the period was 1955–74. To the working series, which were $W(t)=(1-B^{12})(1-B)DSALES_i(t)$, SARIMA models were fitted using the software program TSERIES. The best time-series model for total retail sales was third-order autoregressive plus some seasonal moving average terms. Similarly the best nondurables sales model was second-order autoregressive plus seasonal moving average terms. The best model for durables was third-order autoregressive and seasonally autoregressive plus one seasonal moving average term.

cient in their use of information than the "retailer proxy forecasts." As the correlations in Table 1 between the monthly *changes* in deflated actual sales and the monthly changes in the current-month sales forecasts show, however, the retailer proxy predicts changes in sales nearly as well as the ARIMA forecasts.[10]

B. *Inventory Carrying Costs*

Inventory carrying costs can be broken down into two types. First there are good-specific inventory carrying costs which vary with the storage arrangements, maintenance requirements, and depreciation rates of the goods inventoried. For example, furniture requires more square feet of storage space per dollar of value than does jewelry. These good-specific inventory carrying costs, while important, do not vary very much if at all over time, and therefore, were not considered in specifying this paper's equations designed to explain time-series data. A retail firms's inventory is generally its largest capital investment.[11] The capital costs of financing this inventory investment do vary considerably over time. As a measure of these financial inventory carrying costs, a Jorgenson-Hall service cost of capital measure was constructed as follows:[12]

$$(7) \quad CAPC_i = \frac{P_i(t)}{PC(t)}\left[r(t) - \dot{P}_i^e(t)\right]$$

where $i = T, D, ND$ (for Total Retail, Durables, Nondurables)

$P_i(t)$ = retail price of the ith sector's goods

$r(t)$ = short-term interest rate

$\dot{P}_i^e(t)$ = expected rate of inflation of ith sector's goods over inventory holding period

$PC(t)$ = Consumer Price Index (all items).

With the nominal rate of interest and the expected rate of inflation expressed in annual percentage terms, $CAPC_i(t)$, gives the number of real dollars per year it costs to hold a unit of inventory capital.[13] Equation (7) states that capital costs increase with increases in the real interest rate or the relative price of the goods inventoried. For example, automobile dealers' per unit financial inventory carrying costs have risen in recent years, not only as a result of higher interest rates, but also as a result of the increases in the relative price of automobiles.

Since inventory is held a relatively short period of time, the expected inflation rate $\dot{P}_i^e(t)$ should be for a relatively short future time span. As a proxy for these expectations, two simple extrapolative measures of $\dot{P}_i^e(t)$ were tried alternatively:

$$(8) \quad DP1_i(t) = \left[\frac{P_i(t) - P_i(t-12)}{P_i(t-12)}\right] \times 100$$

$$(9) \quad DP2_i(t) = \left[\frac{P_i(t) - P_i(t-24)}{P_i(t-24)}\right] \times 50$$

Substituting these for $\dot{P}_i^e(t)$ in equation (7) assumes that, at the beginning of the tth month, the rate of inflation over a future period of time equal to the inventory holding period will equal the actual rate of inflation observed over the previous year, or alternatively, over the previous two years.

C. *Other Variables and Data Sources*

With $CAPC_i(t-1)$ substituted for expected per unit inventory carrying costs, and the current-month, one-month ahead, and two-months ahead sales forecasts substituted for expected future sales in equation (3), we

[10]In fact, for durable retail sales the retailer proxy forecast is slightly better. These correlations are over a March 1958 through December 1974 sample period.

[11]Most large retail stores lease their buildings. The other major capital investment is generally their accounts receivable, i.e., the store's credit plan. However, with the widespread use of bank credit cards, less and less of the retail sector's capital is invested in consumer loans.

[12]This user cost of capital measure is completely analogous to the user rental cost of capital utilized in the investment studies of Dale Jorgenson and Robert Hall and recently by Frederick Mishkin as a measure of the rental cost of consumer durables.

[13]Added to this are, of course, the good-specific inventory carrying costs including depreciation.

obtain

(10)

$$y^d(t)=\alpha_0+\beta_1 ESDCM_i(t)+\beta_2 ESD1M_i(t)+\beta_3 ESD2M_i(t)+\alpha_2 CAPC_i(t-1)$$

where $\alpha_1=\beta_1+\beta_2+\beta_3$

Substituting this into equation (2) we obtain

$$(11)\quad y_i(t)=(1-\delta)y(t-1)+\delta\alpha_0+\delta\beta_1 ESDCM_i(t)+\delta\beta_2 ESD1M_i(t)+\delta\beta_3 ESD2M_i(t)+\delta\alpha_2 CAPC_i(t-1)+\varepsilon(t)$$

To this specification, one additional variable was added. If the stores expect sales to be higher than they turn out to be, and if they have extra inventory on hand to meet those higher expected sales, that inventory will still be around at the beginning of the next month. Thus, the following variable measuring the "sales anticipation error" the previous month was added:

$$(12)\quad ERROR_i(t)=ESDCM_i(t-1)-DSALES_i(t-1)$$

The coefficient on $ERROR_i(t)$ is expected to be positive, but less than or equal to one. The greater the extent stores can observe within a month that their sales expectations are incorrect and are able to take corrective actions (such as canceling or increasing orders, or holding a sale), the smaller will be the coefficient on $ERROR_i(t)$. Such sales-anticipation error terms have often been utilized in equations explaining inventories of finished goods since Lovell's 1961 paper.

The dependent variable of the total retail-sector equation was taken to be the appropriately deflated beginning of the month, nominal, seasonally unadjusted retail sector inventory level reported by the U.S. Department of Commerce (USDC). In deciding on the deflation procedure, it is necessary to take into account the accounting methods used for inventory valuation. The two most popular valuation methods are first-in–first-out (*FIFO*) and last-in–first-out (*LIFO*), which was first allowed for tax purposes in 1939 and has grown in popularity in recent years. Retail-sector firms have been slow in adopting *LIFO*, however; a USDC survey in December 1973 showed that only 4.6 percent of retail inventories were valued by the *LIFO* method.[14] Thus, over the 1958–74 sample period, retail inventories can be assumed to have been valued by the *FIFO* method.[15] The more rapid the turnover of inventory, the more closely *FIFO* book value corresponds to current-dollar market value. I followed the deflation procedure used by Martin Feldstein and Alan Auerbach which assumes a constant turnover time and a uniform age distribution.[16]

Total nominal retail sales were deflated by the All Commodities *CPI* subindex reported by the U.S. Bureau of Labor Statistics (BLS). Durable good sales and nondurable good sales were deflated by the durable commodities and nondurable commodities *CPI* subindices, respectively. The short-term interest

[14]Figure quoted to me by John Hinricks of the Bureau of Economic Analysis (BEA) in a telephone conversation.

[15]Given such a small *LIFO* percentage at the end of the sample period, the knowledge that the *LIFO* percentage was even smaller in earlier years, and the complexity and arbitrariness of the procedure for deflating *LIFO* inventories (see Feldstein and Auerbach's Appendix A for details), it was decided that probably the most accurate deflation method would be to assume that all retail inventories were valued by *FIFO*.

[16]The turnover rates utilized by BEA in their deflation of the various retail subsector inventory levels were obtained. These subsector turnover rates were then weighted by the proportion of the total constant dollar inventory levels (as of December 1967) held in the subsector to obtain representative turnover rates for the total retail sector and the durable and nondurable subsectors. Under the assumption of a uniform age distribution, these calculations implied that about six months for durable goods, three months for nondurable goods, and four to five months for the total retail sector would be reasonable assumptions. Hence, I deflated the nominal durable inventory level by a six-month moving average of the *WPI* for durable consumer finished goods, the nominal nondurable inventory level by a three-month moving average of the *WPI* for nondurable consumer finished goods, and the total nominal retail inventory level by a four-month moving average of the *WPI* for consumer finished goods.

rate used to construct the capital cost measures was taken to be the prime bank interest rate, since the relatively small size of most retail firms dictates that they employ bank financing. The price indices used in the construction of the respective capital cost measures were the same ones that were used to deflate the sales series. Those capital cost measures utilizing an expected rate of inflation based on the previous year's experience are designated $CAPC1_i(t)$, while those whose $\dot{P}_i^e(t)$ are based on the last two years experience are designated $CAPC2_i(t)$. The Appendix contains a complete list of variable definitions and their sources.

II. Estimation Results

The specification given by equation (11) plus the sales anticipation error variable was estimated to explain the month-to-month variations in the deflated inventory levels held by the total retail sector, and the durable goods and nondurable goods subsectors. The sample period, identical for all three equations, runs from March 1958 through December 1974. A priori, one would hypothesize that because of the inertia in adjusting inventories, monthly time-series data on inventories would display serially correlated errors. Estimating the equations by ordinary least squares and calculating Durbin's h-statistic confirmed that the estimated error terms of these equations were serially correlated.[17] The combination of serially correlated errors and a lagged dependent variable results in ordinary least squares giving biased coefficient estimates at all sample sizes. To obtain consistent estimates of the coefficients, an instrumental variables estimation method was utilized.[18] These estimated coefficients appear in the first three columns of Table 2. In the next three columns, the estimated coefficients of equations utilizing the alternative ARIMA expected sales proxies are reported. To obtain more efficient coefficient estimates, a first-order serial correlation correction was made using Fair's method and the appropriate additional instruments.[19] These results are reported in the right-hand six columns of Table 2.

As one can observe from Table 2, the estimated coefficients on the lagged dependent variables are statistically very significant (the asymptotic t-ratios are all over 20).[20] The estimated speed-of-adjustment coefficients are reported in the first row of Table 3. These indicate that retail firms adjust their inventories to their target values rapidly, when compared to the speeds of adjustment that have been estimated for manufacturers' inventories. The estimated speeds of adjustment for the total retail sector indicate that 45 to 50 percent of the gap between the actual and the target inventory is closed within each month on average. Similarly the estimates imply that 53.1 percent of the gap is eliminated within one month for nondurable inventories. On the other hand, only 12 to 15 percent of the durable goods gap is eliminated within a month. This means that in three months, between 80 and 85 percent of any gap between actual and target total retail inventories is eliminated. These relatively rapid estimated speeds of adjustment are consistent with the estimated rapid adjustment of inventories to sales anticipation errors, which are indicated by the relatively small estimated coefficients on the forecast error variables. Thus, we can conclude that the results support the use of the stock adjustment model. These estimated speeds of adjustment are consistent with Trivedi who, using monthly seasonally unadjusted data on U.K. total retail inventories, estimated the speed of adjustment to be around .40. They are also consistent with Lovell's 1969 and my 1980b respective estimates of .59 and .72 for the speed of adjustment of department store inventories.

As expected, the estimated coefficients show that expected future sales are the major determinant of retail inventory levels. The

[17]See Johnston (1972, p. 313) for a discussion of this test.

[18]Note that these estimates are consistent independent of the order of the serial correlation present.

[19]The exact procedure followed is described on pages 261–63 of the H. K. Kelejian and W. E. Oates text.

[20]All references to statistical significance refer to the equations estimated using Fair's Method reported in the right-hand six columns of Table 2.

TABLE 2—ESTIMATED RETAIL INVENTORY EQUATIONS

	Dependent Variable is Beginning of Month Inventory of:											
	Estimated by Instrumental Variables						Estimated by Instrumental Variables with Fairs					
Independent Variables	Total Retail Sector *BIDT*	Non-durable Goods *BIDND*	Durable Goods *BIDD*	Total Retail Sector *BIDT*	Non-durable Goods *BIDND*	Durable Goods *BIDD*	Total Retail Sector *BIDT*	Non-durable Goods *BIDND*	Durable Goods *BIDD*	Total Retail Sector *BIDT*	Non-durable Goods *BIDND*	Durable Goods *BIDD*
Constant term	−10.93	−17.75	−.349	−18.82	−19.71	−1.79	2.30	−13.64	.644	−6.09	−16.55	−.98
	(3.58)	(1.93)	(1.805)	(3.68)	(1.81)	(1.90)	(7.00)	(2.88)	(2.808)	(7.33)	(2.71)	(2.85)
Lagged Inventory Level	.622	.495	.893	.566	.483	.880	.549	.468	.878	.510	.469	.850
	(.025)	(.019)	(.028)	(.029)	(.018)	(.033)	(.025)	(.019)	(.031)	(.024)	(.018)	(.031)
Sales Forecast by Retailer Proxy												
Current Month	.331	.347	.260				.366	.364	.289			
	(.026)	(.016)	(.063)				(.017)	(.013)	(.059)			
One-Month Ahead	.229	.249					.249	.257				
	(.021)	(.013)					(.016)	(.011)				
Two-Months Ahead	.061	.115					.073	.101				
	(.022)	(.013)					(.016)	(.011)				
Sales Forecast by ARIMA												
Current Month				.382	.365	.302				.406	.376	.368
				(.029)	(.016)	(.078)				(.017)	(.012)	(.066)
One-Month Ahead				.261	.255					.278	.261	
				(.023)	(.013)					(.015)	(.011)	
Two-Months Ahead				.091	.116					.091	.098	
				(.024)	(.013)					(.015)	(.011)	
Previous Month's Sales Forecast Error												
Retailer Proxy	.014	.074	.024				.131	.153	.008			
Forecast	(.063)	(.053)	(.077)				(.045)	(.040)	(.075)			
ARIMA Forecast				.183	−.011	.052				.226	.038	.074
				(.075)	(.062)	(.119)				(.047)	(.052)	(.091)
Capital Cost Based on Two-Year Expected	−2.356	−.554		−1.984	−.366		−3.498	−.777		−2.854	−.482	
Inflation Proxy	(.495)	(.202)		(.477)	(.188)		(.862)	(.300)		(.886)	(.281)	
Capital Cost Based on One-Year Expected			−.639			−.561			−.852			−.820
Inflation Proxy			(.250)			(.247)			(.363)			(.365)
Rho							.605	.436	.435	.661	.453	.458
R^2 Adjusted	.992	.993	.989	.993	.994	.989	.969	.983	.973	.966	.985	.972
Durbin-Watson	.79	1.12	1.12	.67	1.09	1.08	1.61	1.84	1.83	1.74	2.01	1.80
Standard Error Adjusted	6.696	3.329	4.861	6.553	3.076	4.880	5.496	2.979	4.384	5.014	2.714	4.350
R^2 Adjusted in Terms of Changes							.732	.849	.165	.787	.876	.186

Note: (a) Instruments used consisted of all included exogenous variables lagged one more period than in equation. The lagged dependent variables were treated as endogenous. (b) Estimated (asymptotic) standard errors reported in parentheses below the coefficients. (c) All equations estimated over March 1958 through December 1974 range.

estimated coefficients of both the ARIMA forecasts and retailer proxy forecasts, which were utilized alternatively to measure expected future sales, are positively signed. In the total retail and nondurables inventory equations, the estimated coefficients on these measures test to be statistically different from zero at the 0.5 percent level using a one-tailed t-test. For the durable goods sector, the estimated coefficients on the one-month ahead and two-months ahead forecasts were statistically quite insignificant and were thus dropped from the equations reported in Table 2. The estimated positive coefficients on both forecasts of current-month durable sales test to be statistically different from zero by a one-tailed t test at the 0.5 percent level.

In accordance with a priori expectations, the estimated coefficients on the sales anticipation error measures all are positively signed. Statistically, according to a one-tailed t-test, the coefficients in the total retail sector equations test to be different from zero at the 1 percent level. However, three of the four estimated coefficients on these sales anticipation error measures are statistically insignificant in the nondurable and durable goods equations. The small sizes of the estimated coefficients indicate that retail stores quickly observe that their sales expectations are incorrect and are able to quickly make some adjustments in order levels, advertising, or pricing policies to deal with any inventory disequilibrium generated by the

TABLE 3—ESTIMATED SPEED OF ADJUSTMENT AND ELASTICITY VALUES

	Total Retail Sector		Nondurable Goods Subsector		Durable Goods Subsector	
	Retailer Proxy	ARIMA Proxy	Retailer Proxy	ARIMA Proxy	Retailer Proxy	ARIMA Proxy
Estimated Speed of Adjustment Coefficient,[a] δ	.451	.490	.532	.531	.122	.150
Estimated Point-of-Means Elasticity of the Target Inventory Levels, $y_i^d(t)$, with respect to:[b]						
Sales Forecast by Retailer Proxy for						
Current Month	.558		.577		1.132	
One-Month Ahead	.380		.409			
Two-Months Ahead	.112		.160			
Sales Forecast by ARIMA for						
Current Month		.564		.614		1.166
One-Month Ahead		.386		.428		
Two-Months Ahead		.126		.161		
Sum of Expected Future Sales Measures	1.050	1.076	1.146	1.203	1.132	1.166
Capital Cost Measure	−.065	−.049	−.019	−.012	−.163	−.128

[a]Equal to one minus estimated coefficient on the lagged dependent variable in accordance with equation (11).

[b]The estimated coefficients of each $y_i^d(t)$ equation were derived from estimated coefficients according to equation (11). These coefficients were then utilized to calculate the point-of-means elasticity values.

incorrect sales expectations. These sales anticipation errors played a minor role in explaining the variation of retail inventories held over time since they are quite small in general. For example, the monthly value of the sales anticipation error variable for the total retail sector ranged from −18.66 million to 21.46 million and had a mean value of .366 million and a standard deviation of 7.526 million over the sample period, while actual monthly sales averaged 252 million (1967 dollars).

A priori, I expected a negative sign on the level of financial inventory carrying costs. As reported in Table 2, the estimated coefficients on the capital cost measures are negatively signed in all six equations. By a one-tailed t-test, all these coefficients test to be statistically different from zero at least at the 5 percent level. Capital cost measures constructed on the assumption that expected inflation equals that experienced over the last two years were more significant in explaining total retail and nondurable inventory levels. On the other hand, the capital cost measure based on a one-year expected inflation proxy was more significant in explaining fluctuations in durable goods inventories. Contrary to most previous studies, then, I have found that fluctuations in retail inventory levels depend in a statistically significant manner on fluctuations in financial inventory carrying costs.

The coefficients of the optimum target inventory equation (10) can easily be derived from the estimated coefficients by dividing them by the estimated speed of adjustment. The calculated point-of-means elasticities of each target inventory level $y_i^d(t)$, with respect to each of the independent variables, are given on Table 3. As one would expect, a priori, fluctuations in sales expected in the upcoming month more significantly influence the desired inventory levels than do the sales expected the next month. These in turn have a greater influence on target inventories than do fluctuations in sales expected two months in the future. The sum of elasticities with respect to these three individual sales forecasts gives the eventual response of

the target inventory to an upswing in sales. These sums, reported in Table 3, indicate that the elasticities of target retail inventory levels with respect to future sales are around one.

The estimated elasticities of the target inventory levels with respect to the capital costs measure (reported in the last row of Table 3) indicate that compared to the nondurables subsector, the target inventory level of durable goods is much more sensitive to capital cost fluctuations. The durable goods target inventory elasticity with respect to capital costs is estimated to be between (−.13) and (−.16) while the nondurable elasticity is estimated to be only between (−.01) and (−.02). The capital cost elasticity of the total retail target inventory, which was estimated to be between (−.05) and (−.07) is, as would be expected, almost an average of the durable and nondurable sectors' elasticity values. Fluctuations in capital costs produce substantial changes in target inventory levels despite the seemingly small size of these estimated elasticity values. This is because fluctuations in the capital cost measures tend to be quite large. For example in the 1973 credit crunch, the prime rate doubled from 4.75 percent in March 1972 to 10 percent in September 1974 (it later went to 12 percent). Reflecting this 5.25 percentage point rise in the prime interest rate, the capital cost measure for durable goods $CAPC1D(t)$ rose 4.04 percentage points, the capital costs measure for nondurable goods $CAPC2ND(t)$ rose 1.02 percentage points, while $CAPC2T(t)$ rose 2.32 percentage points. The increases in the capital cost measures were less than the rise in the prime interest rate because expected inflation increased over this period. These increases in capital costs decreased target inventory levels by about 2.3 billion 1973 dollars over the period. Of this, 95 percent was accounted for by the 12 percent fall in desired target inventories of durable goods.

The capital cost elasticity estimates suggest that a 100 percent change in capital costs will result in a change in the overall retail target inventory level of a little over 5 billion 1977 dollars with nine-tenths of that being durable goods. Given the tendency of short-term interest rates to fluctuate widely over the business cycle, such large changes in financial inventory carrying costs are not only conceivable, but have been reasonably common over the last decade. This 5 billion reduction in target retail inventories is, of course, only an impact effect. Lower desired retail inventories mean smaller orders to the manufacturing sector for goods, which in turn will cause lower production, lower employment, and perhaps lower manufacturing sector target inventories. Thus, we can see that the changes in target retail inventory levels resulting from changing capital costs provide another moderately important channel by which monetary policy changes influence the economy.[21] If in fact the target inventory levels of wholesalers and manufacturers are also directly sensitive to short-term changes in financial inventory carrying costs, as theoretically they should be, then clearly the impact monetary policy changes have on target inventory levels is a major channel through which monetary policy influences the real economy. The importance of this channel for stabilization policy is enhanced by the relative speed at which it operates; the lag between a change in capital costs and the decision to change inventory investment seems to be very short.

The summary statistics reported in Table 2 clearly indicate that the overall fits of the estimated equations are good. This is confirmed by examining Figure 1 where the actual beginning-of-the-period inventory values (solid lines) are plotted over time against the respective fitted values (dashed lines). The fitted series generally track very well the movements in actual inventory levels. The durables equation generally experienced most trouble tracking inventory movements in August and September, a time when automobile model changeover interrupts the production of new cars and, in good auto sales years, the normal relationship between expected sales and durable inventories. For example, actual durable inventories fell most

[21]See the recent paper by Lovell (1974) for a theoretical discussion of how monetary policy through this channel of controlling inventory fluctuations could be used for stabilization purposes.

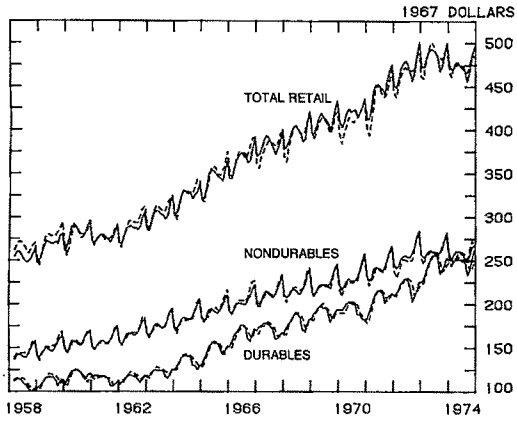

FIGURE 1. PLOT OF ACTUAL VS. FITTED INVENTORY LEVELS

Note: ____ actual; ____ fitted; Units are millions of 1967 dollars.

below predicted levels in the late summer months of 1968, 1972, and 1973, years when auto sales were at all-time record levels. These overprediction errors also show up in the plot of actual versus fitted total retail inventory levels.

III. Estimation Results for Alternative Specifications

The results reported in the previous section demonstrate that fluctuations in capital costs cause changes in target retail inventory levels which are both statistically and economically significant. Since most previous studies of inventory investment, including the recent one by Feldstein and Auerbach, failed to find such an effect, in this section I examine several alternative estimated equations in an effort to explore why my results differ from previous estimates. There are several possible (nonmutually exclusive) explanations.

The econometric techniques employed in this study could account for the difference. This is ruled out, however, by the fact that the ordinary least squares (*OLS*) estimated coefficients on the capital cost measures in similar equations are negatively signed and test to be statistically different from zero. The estimated *OLS* coefficients for the total retail sector are reported in column (1), Table 4. The estimated elasticity with respect to capital costs, reported in the last row of Table 4 is changed very little from the specification previously estimated, which is reported in column (2). The *OLS* estimated elasticity for nondurable inventories is smaller (−.012), while that of the durables sector is larger (−.180) than that obtained before. Since many previous studies utilized seasonally adjusted data, my equations were seasonally adjusted (by adding 11 monthly dummy variables) to see what effect that would have on the capital cost elasticity value. As one can observe from column (3), it lowered considerably the capital cost elasticity. Seasonal adjustment also lowered the estimated capital cost elasticity for the nondurables sector to about zero (+.005), but *raised* it considerably to (−.244) for the durables subsector.[22]

Several alternative measures of capital costs were included to see if my use of the Hall-Jorgenson capital cost measure given by equation (7) helps explain the finding of a significant capital cost effect. These results are reported in columns (4), (5), (6), and (7). The first two capital cost measures are variants of the Hall-Jorgenson capital cost measure. Both have negative and statistically significant estimated coefficients. On the other hand, in column (6) only the prime interest rate was utilized. The estimated coefficient on the prime interest rate is positively signed and statistically significant. The estimated coefficients on the prime interest rate entered alone in equations explaining nondurable inventories and durable inventories also were positively signed. As Feldstein and Auerbach noted, nominal interest rates and the expected rate of inflation theoretically would be expected to move together,

[22] In the seasonally adjusted nondurable equation, the coefficient on the capital cost measure was statistically very insignificant. On the other hand, the coefficient on the capital cost measure in the seasonally adjusted durable inventory equation tested to be statistically different from zero by a one-tailed t-test at the 5 percent level. The unadjusted equations reported previously in Table 2 indicated that capital cost fluctuations mainly affected the inventories of durable goods. The results from the seasonally adjusted equations confirm the size and statistical significance of this effect on durable retail inventories.

TABLE 4—ALTERNATIVE EQUATIONS EXPLAINING BEGINNING-OF-THE-MONTH INVENTORY HELD BY TOTAL RETAIL SECTOR, *BIDT*
(Estimated by Instrumental Variables Using Fair's Method)

	3/1958 through 12/1974							Different Range Used		
	OLS Used	Same	Seas. Adj.	Capital Costs Entered Differently				3/58–12/69	1/70–12/74	1/65–12/74
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Coefficient of:										
Lagged Inventory Level	.748	.549	.960	.562	.380	.556	.538	.510	.454	.481
	(.018)	(.025)	(.035)	(.024)	(.034)	(.028)	(.028)	(.033)	(.056)	(.044)
Sales Forecast by Retailer Proxy										
Current Month	.239	.366	.127	.368	.325	.365	.359	.368	.328	.333
	(.020)	(.017)	(.039)	(.018)	(.014)	(.018)	(.018)	(.021)	(.027)	(.020)
One-Month Ahead	.190	.249	.043	.253	.178	.243	.241	.260	.170	.201
	(.018)	(.016)	(.035)	(.016)	(.013)	(.016)	(.016)	(.019)	(.024)	(.019)
Two-Months Ahead	−.004	.073	−.097	.075	.008	.063	.067	.063	.021	.042
	(.018)	(.016)	(.034)	(.016)	(.013)	(.016)	(.016)	(.019)	(.024)	(.019)
Previous Month's Sales	−.012	.131	−.007	.129	.136	.119	.115	.131	.142	.122
Forecast Error	(.056)	(.045)	(.032)	(.046)	(.038)	(.048)	(.047)	(.053)	(.083)	(.056)
Capital Cost Measure,	−1.562	−3.498	−.083					.659	−3.754	−5.930
$CAPC2T(t-1)$	(.431)	(.862)	(.333)					(1.268)	(1.072)	(1.344)
Nominal Capital Cost Measure,				−.0262						
$PC(t-1)\cdot CAPC2T(t-1)$				(.0078)						
Relative Price,					−954.9					
$PCC(t-1)/PC(t-1)$					(106.7)					
Real Rate of Interest,					−3.726					
$[\text{Prime}(t-1)-DP2T(t-1)]$					(.727)					
Prime Interest Rate,						1.650	−1.671			
$PRIME(t-1)$						(.719)	(.978)			
Expected Inflation Proxy,							3.444			
$DP2T(t-1)$							(.813)			
Constant Term	−9.57	2.30	−2.85	−7.07	1069.0	−15.86	.86	−1.87	101.9	72.05
	(3.20)	(7.00)	(3.64)	(5.86)	(120.4)	(5.14)	(6.48)	(7.76)	(23.59)	(21.27)
Rho		.605	.129	.600	.610	.577	.559	.594	.411	.647
R^2 Adjusted	.994	.969	.998	.970	.978	.971	.974	.948	.909	.906
Durbin-Watson	1.35	1.61	1.93	1.62	1.70	1.50	1.52	1.55	1.75	1.67
Standard Error	5.978	5.496	3.267	5.508	4.578	5.653	5.533	5.173	5.291	5.739
Est. Elasticity of	−.052	−.065	−.017	−.051	−.051	.059	−.058	−.014	−.032	−.077
Target Inventory					(real		(*PRIME*)			
Level With Respect to					rate)		+.056			
Capital Cost Measure							(*DP2T*)			

Note: (a) See note (a) of Table 2. (b) See note (b) of Table 2. (c) All equations except (1) were estimated by instrumental variables using Fair's method.

but have coefficients of the opposite sign in inventory equations.[23] Thus, omission of either will tend to bias the coefficient of the included variable towards zero. When the expected rate of inflation was added to our inventory equations, the signs of the estimated coefficients on the prime rate were negative. Such an equation for the total retail sector is reported in column (7) of Table 4. Both the coefficients on the prime rate and on the expected inflation proxy, $DP2T(t-1)$, are statistically significant. Their estimated point-of-means elasticities are nearly identical in size and of opposite sign in accordance with theoretical expectations. Thus, it can be concluded that my use of a service cost of capital measure does help to account for the finding of a significant capital cost effect.

The use of data extending into the 1970's also helps explain my finding. Using data through 1969, as is reported in column (8), yields a positively signed, statistically insignificant coefficient on the Hall-Jorgenson capital cost measure. Similar results were obtained for nondurable and durable inventories. The largest capital cost elasticities were obtained over a mid-1960's through 1974 sample period, like that reported in column (10). This is understandable since 1958–64 was, relatively speaking, a period of interest rate and price level stability.

[23]The simple correlation between the prime rate and the expected inflation proxy *DP2T* was .90 over the sample period.

Thus, the use of a service cost of capital measure and the use of seasonally unadjusted data extending into the 1970's seem to be the major factors which contribute to my finding that fluctuations in capital costs significantly influence target retail inventory levels.

IV. Inventory Disequilibrium

Using the estimated coefficients, the desired target inventory levels over time were calculated using equation (10). These estimated target inventory levels were then subtracted from the respective actual inventory series, yielding estimates of inventory disequilibrium in each sector. In Figure 2, inventory disequilibrium of the total retail sector is plotted against time. This plot confirms what the estimated speed of adjustment indicated earlier: retail inventories are adjusted quite rapidly to their desired levels, that is, disequilibrium does not persist very long. As can be seen from Figure 2, prolonged excess retail inventories occurred only during the recessionary periods which are indicated by the shaded areas.[24]

Examination of similar plots of the estimated disequilibrium of durable goods and nondurable goods reveals rather different patterns. Generally, the nondurable disequilibrium measure fluctuates in a narrow range around zero indicating that 1) nondurable inventories seldom get very far away from their target values, and 2) when they do, adjustment towards the target value occurs very rapidly. On the other hand, despite the relatively smaller size of durable inventories, the size of disequilibrium experienced by durable retail inventories is larger than that of nondurables and persists much longer; this reflects the much slower estimated speed of adjustment of durable inventories. Also, during recessionary periods, the buildup of durable inventories starts before the buildup of nondurable inventories. For durable goods, the largest accumulation of excess inventories occurred during the four recessionary periods. Durable inventories were most deficient in late 1972 and early 1973 as the economy overheated and in 1963–64. Nondurable inventories also have been excessive following the beginning of the last three recessionary periods. Notable periods of deficient nondurable inventories occurred during most of 1959, the last half of 1965 and most of 1966, and the last half of 1968. These generally represent boom periods immediately preceding business cycle peaks.

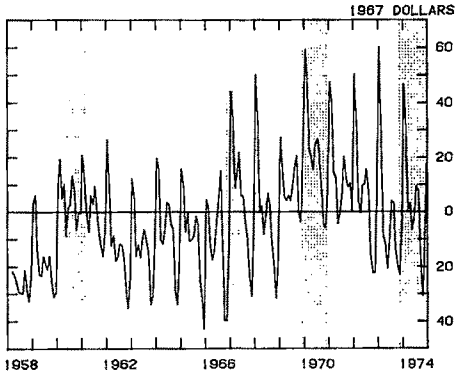

FIGURE 2. INVENTORY DISEQUILIBRIUM OF TOTAL RETAIL SECTOR

V. Summary

The results obtained here suggest that retail inventories are on average adjusted rapidly to their target levels. These target inventory levels were shown to depend significantly on fluctuations in financial inventory carrying costs. Target durable inventories seem to be much more sensitive to fluctuations in capital costs than are nondurable target inventories. On the other hand, nondurable inventories adjust considerably faster to their target levels than do durable inventories. Further research is needed to see whether these generalizations hold up at a more disaggregated level.[25] In any case, the

[24]The official recessions during the sample period according to the National Bureau of Economic Research occurred from April 1960 through February 1961; December 1969 through November 1970; and from November 1973 through March 1975. Also the period November 1966 through May 1967 is considered as a recessionary period even though the downturn did not persist long enough to be classified as an official NBER recession.

[25]It is my opinion that the inventories of some nondurable goods like clothing are much more sensitive to financial inventory carrying costs than are the inventories of other goods like food.

results reported in this paper establish clearly that fluctuations in interest rates do significantly affect aggregate target retail inventory levels and thus confirm the existence of another channel by which monetary policy influences the economy. Further studies of the dependence of the manufacturing and wholesaling sectors' inventories on financial inventory carrying costs must be done before an evaluation of the importance of this channel, relative to other channels of monetary policy, can be made.

Appendix: Definitions of Variables and Sources of Data

BIT
Estimated Book Value at cost of merchandise held by retail stores nationwide at the beginning of the month, not seasonally adjusted, in millions of current dollars. *Source*: BEA.

BID
Same as above except held by retail stores selling mainly durable goods. *Source*: BEA.

BIND
Same as above except held by retail stores selling mainly nondurable goods. *Source*: BEA.

RAST
Total sales by retail stores unadjusted for seasonal variation and trading day differences in millions of current dollars. *Source*: BUS STAT, SCB.

RASD
Total sales by durable goods retail stores. *Source*: BUS STAT, SCB.

RASND
Total sales by nondurable goods retail stores. *Source*: BUS STAT, SCB.

PC
Consumer Price Index (all items) (1967=100), seasonally unadjusted. *Source*: NBER TAPE (symbol *PC*).

PCC
All Commodities Index of the Consumer Price Index (1967=100), seasonally unadjusted. *Source*: NBER TAPE (symbol *PCC*).

PCN
Nondurable Commodities Index of the Consumer Price Index (1967=100), seasonally unadjusted. *Source*: NBER TAPE (symbol *PCN*).

PCD
Durable Commodities Index of the Consumer Price Index (1967=100), seasonally unadjusted. *Source*: NBER TAPE (symbol *PCD*).

DSALEST
Deflated actual total retail sales (*RAST/PCC*).

DSALESND
Deflated actual nondurable sales (*RASND/PCN*).

DSALESD
Deflated actual durable retail sales (*RASD/PCD*).

PRIME
Prime Bank Interest Rate. *Source*: NBER TAPE (symbol *FYPR*).

PWFC
WPI Consumer Finished Goods. *Source*: NBER TAPE (symbol *PWFC*).

PWMDC
WPI Durable Consumer Finished Goods. *Source*: NBER TAPE (symbol *PWMDC*).

PWFOOD
WPI Consumer Finished Goods, Foods. *Source*: NBER TAPE (symbol *PWFOOD*).

PWMNC
WPI Other Nondurable Consumer Finished Goods. *Source*: NBER TAPE (symbol *PWMNC*).

PWCWND
$.3203\ (PWFOOD) + .6797\ (PWMNC)$ where weights represent average inventory composition.

RITDEF
$(PWFC + PWFC(-1) + PWFC(-2) + PWFC(-3))/4.0$

DURDEF
$(\mathrm{PWMDC} + \mathrm{PWMDC}(-1) + \mathrm{PWMDC}(-2) + \mathrm{PWMDC}(-3) + \mathrm{PWMDC}(-4) + \mathrm{PWMDC}(-5))/6.0$

NONDEF
$(PWCWND + PWCWND(-1) + \mathrm{PWCWND}(-2))/3.0$

BIDT
Deflated Beginning of Month Total Retail Inventory (*BIT/RITDEF*)

BIDD
Deflated Beginning of Month Durable Inventory (*BID/DURDEF*)

BIDND
Deflated Beginning of Month Nondurable Inventory (*BIND/NONDEF*)

Sources of Data

BEA
Bureau of Economic Analysis, U.S. Department of Commerce directly supplied inventory data, revised to reflect the 1973 *Retail Trade Annual Report*. Similar data is reported in *Business Statistics*.

BUS STAT
Business Statistics, published semi-annually by the U.S. Department of Commerce, Bureau of the Census, and Bureau of Economic Analysis.

SCB
Survey of Current Business published by the U.S. Department of Commerce.

NBER TAPE
National Bureau of Economic Research data tape, as maintained by the Wesleyan University Public Affairs Center's Data Laboratory.

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Dynamic Programming Models of Fishing: Competition

By DAVID LEVHARI, RON MICHENER, AND LEONARD J. MIRMAN*

It is natural to consider the stock of any renewable resource as a capital stock and treat the exploitation of that resource in much the same way as one would treat accumulation of a capital stock. This has been done to some extent by Colin Clark and Gordon Monro and by Ngo Van Long, whose papers contain a discussion of this point of view. However, the analysis is much simpler than it appears in the literature especially since the interaction between markets and the natural biological dynamics has not been made clear. Three issues which have been raised only tangentially are important for the understanding of the economics of renewable resources. The first arises from the fact that the fish population might not be able to sustain the market determined amount of fish and hence should be allocated optimally over time. Second, there is the cost externality. Here costs are affected by the size of the stock of fish which again affects the optimal allocation over time. The third issue is how central planning (typically used in capital theory) can be employed as a tool in analyzing a decentralized economy with perfect futures markets and property rights.

In this paper a simple framework, using only elementary mathematical techniques, will be provided in which many important results new to the literature, as well as many familiar results, can be derived. One bonus of this approach is that much of the previous literature can be organized and rationalized. The simplicity of the mathematics has the effect of revealing the underlying economic intuition of the subject. Throughout the paper, as a matter of convenience, the self-renewing resource will be referred to as "fish." However, it should be clear that the analysis is perfectly general in that it can be applied to any self-renewing resource. In fact, by specializing the production function, an elementary exposition of the theory of *exhaustible* resources is implicit.

There are two main sections to this work plus an Appendix. The first section analyzes the time path of prices, output, and resource stock under the assumption of free-entry competition, and the second section studies "optimal planning" (or perfect competition). In the first part of the discussion of each market structure, extraction costs are assumed to be independent of the size of the fish stock. In the second part of each section this assumption is relaxed. Finally the Appendix contains several of the results used in the body of the paper.

The case of free-entry competition can be treated in a very simple manner. Each period's output is determined by the intersection of the demand and marginal harvesting cost curves (i.e., supply equals demand). Subtracting this output from the natural dynamics yields the dynamics of free-entry competition. Using this technique, it is easy to see the conditions under which free-entry competition leads to the exhaustion of the stock of fish. Furthermore, the free-entry case serves as a benchmark by which to evaluate the effects of the institution of property rights on the exploitation of the resource.

The case of a centrally planned economy is studied next. This case is shown to be identical to a competitive outcome in which property rights are clearly defined and prices and outputs are endogenously determined so as to be consistent with demand conditions. One result, coincidentally, is that it is possible that the optimal solution might be obtained without property rights. The tech-

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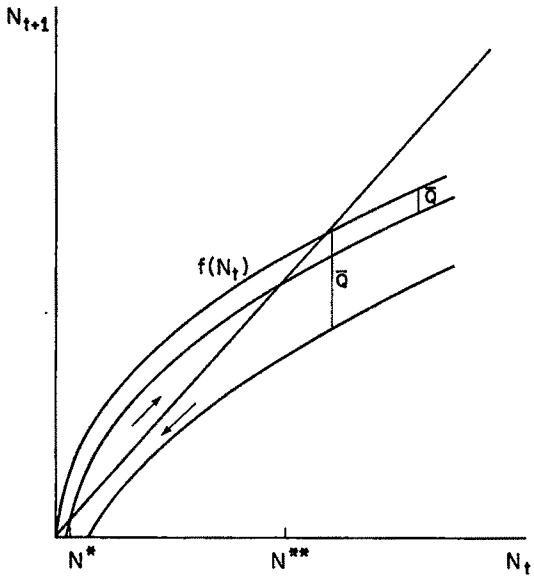

FIGURE 1

niques used here to derive competitive equilibrium with endogenous price paths have been successfully applied in other areas of economics, see, for example, Robert Lucas and Edward Prescott. The application of these techniques to the self-renewing resource problem yields results which are much more appealing than those which arise from the "exogenous and constant price" paradigm widely resorted to in the literature on fishing.

Several examples are given of the dynamic behavior of the fish population when output is optimally determined. These illustrate the wide range of qualitatively different paths which can result from optimal exploitation of the stock. It is shown that these different qualitative paths follow quite intuitively from "rate-of-return" considerations. Indeed, a major aim of the paper is to show that apparently complex and mysterious results in the literature become transparent within this rate-of-return framework.

The monopoly case, which is studied in the same optimal dynamic framework paralleling that of the "perfect competition" case, is studied in a separate paper.

Following most of the renewable resources literature, fish are assumed to follow a growth rule of the form $N_t = f[N_{t-1}] - Q_t$, where N_t is the size of the stock of fish at time t, Q_t is the size of the harvest or output, and f has the following properties:

$$f'>0, f''<0, f(0)=0,$$

$$f'(0)\leq\infty, f'(+\infty)=0.$$

The function f, then, has all the properties usually associated with the production function in a neoclassical growth model, with the exception that $f'(0)$ may be finite. Consequently, the graphical depiction is quite familiar, as is seen from Figure 1.

With respect to the market, it will be assumed throughout that the market demand function for fish as well as the cost function are the same in each period. Moreover, throughout the paper the supply curve should be interpreted as the industry marginal harvesting cost curve.

I. Free-Entry Competition

A. *Costs do not Depend on the Size of the Fish Population*

In this section we consider a fish population governed by the general biological law of growth depicted in Figure 1 and a market for fish which is characterized by a large number of firms. It turns out, in this case, that the equilibrium occurs where the marginal harvesting cost and demand are equated. The marginal harvesting cost, however, does not take into account the shadow price associated with fish. In particular, the fish population might not be able to sustain the extraction of a fixed number of fish which would be determined by the intersection of the supply and demand curves. In this case the amount of fishing in the present affects the amount of fishing in the future. Moreover, this effect cannot be internalized unless there was a mechanism (for example, the assignment of fishing rights) which would affect an "optimal" allocation of fish over time. In the absence of such a mechanism there will exist no way to coordinate the quantities supplied to the market at different points of time. This is precisely the market

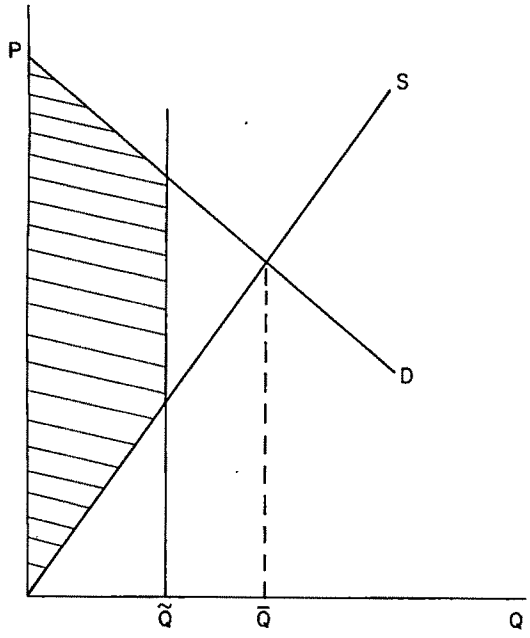

FIGURE 2

structure of free-entry competition. In particular, free-entry competition is a market organization in which fishing grounds are part of the public domain and there are no fees or restrictions involved in their use.

Since production costs are assumed to be independent of the size of the fish stock, the dynamics of free-entry competition are quite straightforward. The market structure is represented in Figure 2, where the demand function is given. The supply function is the sum of firms' marginal cost functions, and the equilibrium output $\bar{Q}$ is the intersection of the demand and supply curves, which would prevail so long as fish were available.

The dynamics of the fish population under these market conditions follow the difference equation, $N_{t+1}=f(N_t)-\bar{Q}$. The dynamics can be drawn by simply subtracting $\bar{Q}$ from the $f(N_t)$ curve in Figure 1. There are two distinguishable cases, depending upon whether or not $\bar{Q}$ is potentially sustainable. In Figure 1, the middle curve represents the case in which $\bar{Q}$ is potentially sustainable. If the initial stock of fish, N_0, is greater than N^*, the fish stock will converge to N^{**}. In this situation, fish are a free good since $\bar{Q}$ fish can be extracted indefinitely and the fish population would be able to sustain itself. Consequently, if there were fishing rights when $N_0 \geqslant N^*$, the price of fishing rights would be zero. The classic case of competitive overfishing occurs if $N_0 < N^*$. In this region fish are no longer a free good since demand cannot be met for all time from the available supplies. For efficiency, fishing rights should bear a positive price. If fishing grounds were private property, there would be a market in fishing rights and they would bear a positive price. Alternately, one could imagine a government agency which regulates fisheries and rations access to the fishing grounds in some way. In the absence of one of these remedies, if $N_0 < N^*$, extermination of the fish in finite time is certain since the equilibrium at N^* is unstable. At N^*, output $\bar{Q}$ is just sufficient to exhaust the natural increase in the fish population. Should demand increase by one unit, or if $N_0 < N^*$, the fish would be headed for eventual extermination. Should demand decrease by one unit, or $N_0 > N^*$, the fish stock would grow to N^{**}.

In Figure 1, on the lowest curve, $\bar{Q}$ is larger than any sustainable output. Extinction under free-entry competition occurs in finite time *regardless of the size of the initial stock*. An efficient solution would require either regulation or the allocation of fishing rights.

B. *The Case where Cost of Harvesting does Depend on Stock Size*

In this section it is assumed that the size of the stock of fish affects the marginal cost function since a larger number of fish makes each additional catch easier and hence cheaper. Equilibrium output will depend upon the size of the fish stock since it is a parameter in the marginal harvesting cost curve. In theory, one could derive the relationship between the quantity supplied and the stock of fish by taking a grid of values for N and finding the intersection of the supply and demand curves. This is done for an example in Figure 3.

In Figure 3 it is assumed that, for small values of the fish stock ($N \leqslant 5$), the market supply of fish will be zero. However, this is

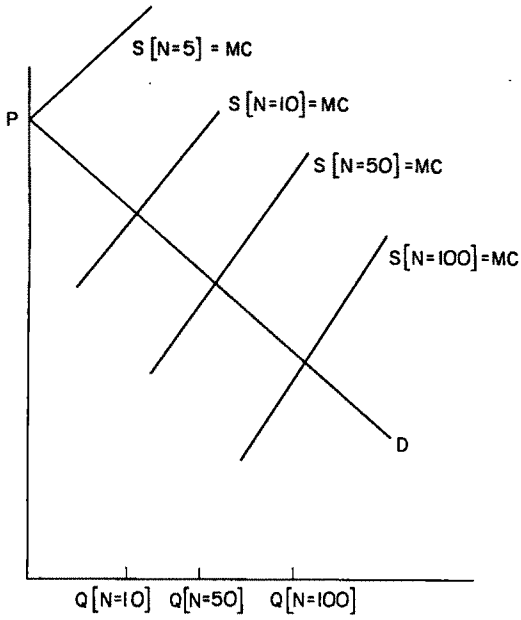

FIGURE 3

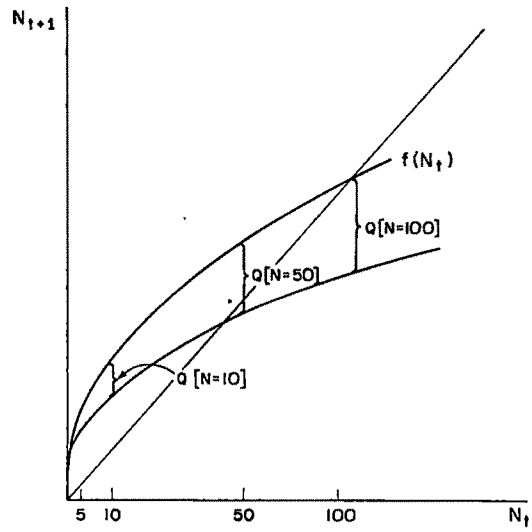

FIGURE 4

not generally the case. It is possible that, no matter how small the stock of fish, the market equilibrium quantity of fish will remain positive. Hence even in this case the possibility of depleting the stock of fish cannot be excluded.

Once again the dynamics are quite easy to draw by subtracting the outputs for each level of the stock of fish from the natural dynamics. This is done in Figure 4.

The points, when connected, describe the dynamics of the system. As drawn in Figure 4 increased costs for small stock sizes make it infeasible to fish the species to extinction, even under conditions of free entry.

Figure 5 considers another possible case. The portion of the diagram above N^* bears a superficial resemblance to the free-good portion of Figure 1. Note though that in Figure 5, even above N^*, each fish harvested raises the cost to all competitors. This cost is not internalized in a free-entry regime. Consequently the portion of the diagram above N^* is no longer optimal. This, then, is a second and, in some sense, independent means in which "overfishing" can occur in a free-entry regime. Note that, paradoxically, overfishing of this sort need not result in eventual extinction. In fact, the cost conditions decrease the likelihood that eventual extinction is economically feasible.

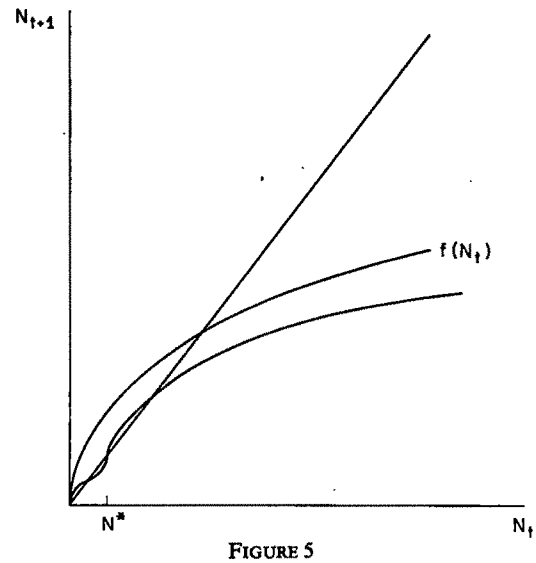

FIGURE 5

II. The Optimum-Path Competition with Privately Owned Fishing Grounds

A. *Costs do not Depend on the Size of the Fish Population*

This section deals with the solution of the optimal allocation of fish over time. As in

the previous section a perfectly competitive economy is assumed, however, here we assume perfect foresight or equivalently well-established futures markets and the existence of property rights. It is frequently the case in economics that the competitive outcome with well-defined property rights corresponds formally with the solution that would result from a central planner optimizing an appropriate measure of social welfare. This is one such case. Whether one wishes to consider the formal solution as a "competitive" solution or as a "centrally planned" solution is a matter of ideological preference. Before discussing the competitive market and the corresponding dynamics of the fish population, it is first shown why these two solutions are formally the same.

For simplicity, assume that there are M firms, each identical and operating from its own lake. The number M is assumed to be very large so that the influence of any one firm's output on the market price may safely be neglected.

There is a conflict here between simplicity of exposition and generality that must be addressed. It is easiest to work in terms of an aggregate "production function"—$f(N)$. However, by introducing separate lakes, to sketch a reasonable model in which fishing rights are owned, the door has been opened to situations in which aggregate production depends not simply on N, but on the distribution of fish across lakes! To avoid this difficulty, which affects both the centrally planned and competitive economy symmetrically, some simplifying assumptions will be made. This is done basically to simplify the mathematics and to allow graphical analysis in terms of a single state variable.

First, the function $f(N)$ is equivalent to $\hat{F}[N, \bar{L}]$, where $\bar{L}$ is the fixed size of the total body of water. The function $\hat{F}$ can reasonably be taken as having constant returns to scale. Let the M lakes each have size $\bar{L}/M$, and assume the initial fish population is divided evenly among them. Finally assume that each fishery faces an identical cost structure. The symmetry imposed guarantees that the fish population in each lake will *always* be identical, as will output from each lake.

Define $n_t = N_t/M$, and $q_t = Q_t/M$. Here n_t and q_t are, respectively, population and output per lake. Under these assumptions the aggregates may be written as

$$\sum_{i=1}^{M} n_t = \sum_{i=1}^{M} \hat{F}\left[n_{t-1}, \frac{\bar{L}}{M}\right] - \sum_{i=1}^{M} q_t$$

Hence $$N_t = M\hat{F}\left[n_{t-1}, \frac{\bar{L}}{M}\right] - Q_t$$

or $$N_t = \hat{F}[N_{t-1}, \bar{L}] - Q_t = f(N_{t-1}) - Q_t$$

This finesses the aggregation problem, since it reduces the dynamics of the aggregate population to the simple dynamics considered earlier.

Suppose a representative firm maximizes the present value of its profit stream:

$$\max_{q_t, n_t} \sum_{t=1}^{\infty} \beta^{t-1}\pi_t = \max_{q_t, n_t} \sum_{t=1}^{\infty} \beta^{t-1}[P_t q_t - C(q_t)]$$

subject to $n_t = \hat{F}[n_{t-1}, \bar{L}/M] - q_t$.

Here P_t is the price at time t which is determined by Q_t, and $C(q)$ is the cost function. Moreover it is assumed that the profit function $\pi(q)$ is strictly concave. Finally, $\beta = 1/1+r$ where r is the market rate of interest.

Each firm takes the price vector $[P_0, P_1, \ldots, P_t \ldots]$ as given. These prices may be thought of as determined in a futures market under conditions of perfect foresight. The condition for equilibrium in this market is that $P_t = D[Q_t]$; that is, all future prices are consistent with demand conditions.

Explicitly, the Lagrangian for this problem is

$$L = \sum_{t=1}^{\infty} \beta^{t-1}\{P_t q_t - C(q_t) + \lambda_t[\hat{F}(n_{t-1}, \bar{L}/M) - n_t - q_t]\}$$

The first-order conditions are

$$\frac{\partial L}{\partial q_t}: P_t - C'(q_t) = \lambda_t$$

and $\frac{\partial L}{\partial n_t}: \beta\lambda_{t+1}\frac{\partial \hat{F}[n_t, \bar{L}/M]}{\partial n_t}=\lambda_t.$

A discussion of these conditions will be deferred until the corresponding conditions are derived for the case of a central planner.

For the problem of a central planner, a measure of community welfare is needed. One common measure of social welfare is the sum of producer's and consumer's surplus, represented for a single period in Figure 2 by the shaded area which measures the social welfare associated with the output $\tilde{Q}$. For this dynamic problem, let us take as a social welfare measure the discounted sum of these single period measures. Since the cost function for each lake is $C(q)$, the industry cost function is $\tilde{C}(Q/M)M$. Hence, the industry marginal cost function is $C'(Q/M)$. Let $\tilde{C}'(Q)=C'(Q/M)$. Hence the formal problem is

$$\max_{Q_t, N_t} \sum_{t=1}^{\infty} \delta^{t-1}\left[\int_0^{Q_t}[D(s)-\tilde{C}'(s)]\,ds\right]$$

subject to $\quad N_t=f(N_{t-1})-Q_t$

Here $0<\delta<1$ is the social rate of time preference. So the Lagrangian is

$$L=\sum_{t=1}^{\infty} \delta^{t-1}\left\{\int_0^{Q_t}[D(s)-\tilde{C}'(s)]\,ds\right.$$

$$\left.+\lambda_t[f(N_{t-1})-Q_t-N_t]\right\}$$

and the first-order conditions are

$$(1) \qquad \frac{\partial L}{\partial Q_t}: D(Q_t)-\tilde{C}'[\tilde{Q}_t]=\lambda_t$$

$$(2) \qquad \frac{\partial L}{\partial N_t}: \delta\lambda_{t+1}\frac{\partial f(N_t)}{\partial N_t}=\lambda_t$$

Comparing the two sets of conditions, note that

(a) Because of our assumption of equilibrium in the futures market $P_t=D[Q_t]$.
(b) $\partial f(N_t)/\partial N_t=\partial\hat{F}(n_t, \bar{L}/M)/\partial n_t$ by the constant returns to scale of $\hat{F}$.

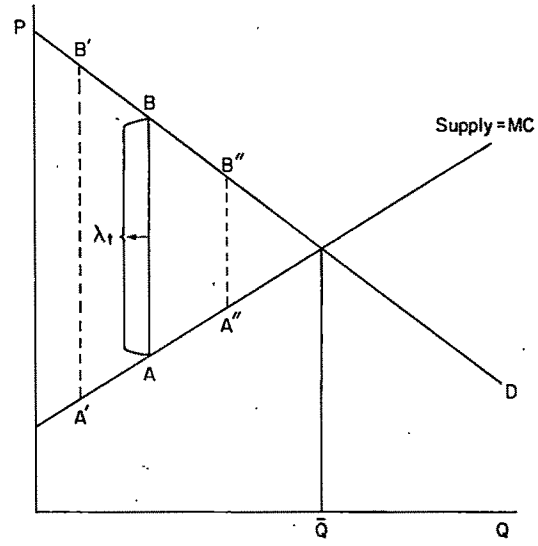

FIGURE 6

(c) $C'[q_t]=\tilde{C}'[Q_t]$.
(d) The social rate of time preference is assumed to equal the market rate of time preference, i.e., $\delta=\beta=1/1+r$.
(e) Both the competitive industry and the planner must satisfy the same transversality conditions, with initial stock N_0 and $\beta^t\lambda_t N_t\to 0$, as $t\to\infty$. This guarantees that the solution paths are identical.

The economics of the first-order conditions are best explained by resorting to Figure 6. Mathematically, λ_t is the marginal profit made by harvesting an additional fish at time t, that is, the *rent* that accrues to the owner of a fish as a result of its scarcity. This rent, which arises from the inability of the fish population to sustain $\bar{Q}$ indefinitely, is internalized in this case, but not in the free-entry case. Figure 6 makes it clear that λ is represented by the line AB.

Condition (2), on the other hand, shows that this rent increases or decreases over time depending on whether or not $1+r$ is greater than or less than $f'(N)$.

If $1+r$ is greater than f', the length of the line AB grows to, say, $A'B'$. If $1+r$ is always greater than f', the price continues to rise and output to shrink. Conversely, if $1+r$ is less than f', the line AB shrinks to, say, $A''B''$. So long as $1+r$ is less than f', the price continues to fall and output to in-

crease. It may not be obvious, but it can be shown using techniques similar to those in the Appendix that the optimal output can be written as a function of the stock of fish.

If $1+r$ ever equals f', price and output will remain constant. The condition that $1+r$ equals f', then, implies that $N_{t+1}=N_t$, so that there is a steady state corresponding to the point at which this condition is met. However this remark is subject to one qualification. The condition that $1+r$ equals f' arises from the necessity of equating the present value of marginal "rents" in successive periods. It is only relevant when fish are not a free good.

It may seem strange that an equilibrium exists where the line AB in Figure 6 has a positive length. It would appear that competitive firms are making positive profits in equilibrium. The explanation is that the supply curve drawn is exclusive of rental fees for the use of a lake. These fees are a cost to the individual firms, and hence the profits shown in the diagrams are illusory.

The interpretation of $1/\beta f'(N_t)$ is straightforward. It compares the biological growth rate of fish to the market rate of interest. In particular condition (2) may be rewritten as

$$\frac{\lambda_{t+1}}{\lambda_t} f'(N_t)=1+r$$

or

$$\left\{1+\frac{\Delta\lambda_t}{\lambda_t}\right\} f'(N_t)=1+r$$

where $\Delta\lambda_t=\lambda_{t+1}-\lambda_t$. The term $\Delta\lambda_t/\lambda_t$ is simply a "rate of return" which results from the appreciation or depreciation of fish; $f'(N_t)\{1+\Delta\lambda_t/\lambda_t\}$, then, is simply the total rate of return resulting from leaving a fish in the sea. In equilibrium, this must equal the rate of return which could be achieved by selling a fish today and investing the proceeds at the market rate of interest. If $1+r>f'(N_t)$, then $1/\beta f'(N_t)>1$. In this case fish grow more slowly than an investment at the market interest rate. Hence it is best to harvest fish today and invest the proceeds. This incentive to immediate harvesting causes the fish stock to decline. The process is only limited by the fact that harvesting more fish today will depress today's marginal profits and increase future marginal profits. Harvesting will proceed until the anticipated increase in the marginal profitability of fish is adequate to offset their slow biological growth rate. In this case, fish must *appreciate* in value to remain competitive with alternate investments. The appreciation reflects increasing scarcity.

Conversely, if $1+r<f'[N_t]$, then $1/\beta f'[N_t]<1$. This is simply the opposite case. If fish grow at a rate greater than the market interest rate, then firms are better off holding them in the sea for sale in the future. This incentive to forego harvesting causes the fish stock to grow. The process is limited by the fact that withholding fish from today's market will increase today's marginal profits, while depressing future marginal profits. Harvesting will be restricted until the anticipated decrease in the marginal profitability of fish is sufficient to offset their rapid biological growth rate. In this case, fish must *depreciate* in value to remain competitive with alternate investments. The depreciation reflects decreasing scarcity.

Finally, suppose $1/\beta f'[N_t]=1$, so that the biological growth rate of fish is equal to the market rate of interest. Firms would then be indifferent between selling fish and holding them for future sale which implies that output is just sufficient for the fish stock to exactly reproduce itself. In this situation a dynamic equilibrium or steady state would ensue. If output were greater, the fish stock would fall, and future prices would be higher than current prices. This state of affairs cannot be an equilibrium, since it would pay each firm to reduce output in order to profit from the next period's higher prices. Conversely, if output were smaller, the fish stock would increase, and future prices would be lower than current prices. This state of affairs cannot be an equilibrium, since it would pay each firm to increase output in order to profit from high current prices. Hence the only equilibrium is the one in which both output and the size of the fish stock are constant. Fish must maintain a constant value to remain competitive with alternate resources. The constant value reflects a constant level of scarcity.

Suppose that $1/\beta f'(N_t)>1$, so that the fish stock is declining. Under what conditions would it be optimal to allow output and the fish stock to be reduced to zero in finite time? The condition can be seen clearly from Figure 6. The line AB is growing through time (the direction of the arrow). If it reaches $Q=0$ in finite time, this implies that it is optimal to allow $Q=0$ and hence $N=0$ in finite time. Two conditions are sufficient for this.

1) The "speed" at which AB grows cannot "die out" as $Q\to 0$. Mathematically, $1/\beta f'(0)>\varepsilon>1$ will suffice. This means that fish growth rates cannot approach the market interest rate asymptotically as the stock of fish approaches zero. The case $1/\beta f'(0)=1$ presents problems and is not of sufficient interest to go into here. Thus it will be ignored.

2) The demand curve must touch, and not just asymptote to, the $Q=0$ axis. A demand curve asymptotic to the $Q=0$ axis corresponds to the case in which fish are an absolute necessity, so that there is no price so high that some quantity could not be sold. Mathematically, this requires that $\pi'(0)\equiv D(0)-\tilde{C}'(0)=+\infty$. Here $\pi'(0)$ denotes the marginal profit which could be attained from selling fish when none are available.

It is implicitly assumed here that if Q declines to zero, N also must decline to zero. This can be shown by a simple argument. Suppose it was not the case. If Q equals zero, but N is not equal to zero, the Kuhn-Tucker conditions imply that

(A) $D(0)-\tilde{C}'(0)\leqslant\lambda_t$;

(B) $\lambda_{t+1}=(1/\beta f')\lambda_t$.

Since Q has declined to zero, $\beta f'<1$, and λ_t is increasing, by (B). Hence once Q equals zero, condition (A) will be met for all time, and Q will always be zero. This is clearly not an optimal path, since it can be dominated by following the same path until the first time Q equals zero, and then setting Q equal to the minimum of $\bar{Q}$ and N.

Note that if $\pi'(0)$ is finite and $\beta f'>1$, so that fish are a good investment, it is possible that the optimal path involves zero output in the initial periods, and positive output thereafter. (For an example of this sort of path, see Mirman.) The behavior of the fish population and its shadow price clearly depends on the interplay of market conditions and the natural dynamics of the fish population. Many interesting possibilities can arise. Several of these will be discussed and illustrated below.

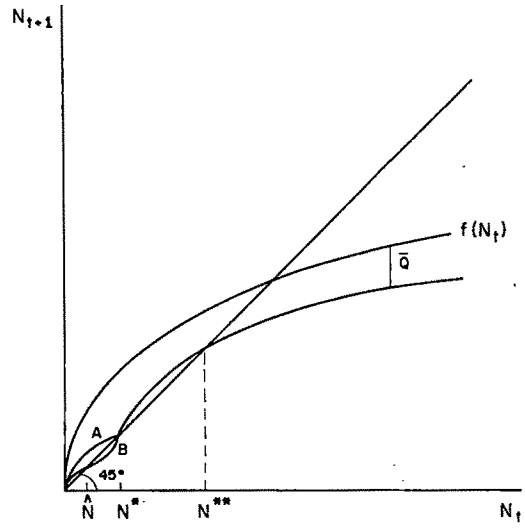

FIGURE 7

First suppose that the market supply $\bar{Q}$ is sustainable. There are then several possible implications for both the long-run supply of fish and the eventual shadow price of fish. For example, in Figure 7, curve A (below N^*) represents a situation in which $\bar{Q}$ is always the steady-state quantity of fish and in the long run the shadow price of fish is zero. This case requires that $1/\beta f'(N^*)\leqslant 1$. Above N^*, fishing rights are a free good, that is, $\bar{Q}$ can be produced indefinitely. Below N^* fish are scarce, but for all initial stocks in the interval $(0, N^*)$, the fish stock will grow to N^*, and the rent on fish will fall to zero. In Figure 6 this is the case in which the line AB shrinks to zero and output grows to $\bar{Q}$.

If $1/\beta f'(N^*)>1$, but $1/\beta f'(0)<1$, then there exists three steady states (including N^{**}) as seen from curve B of Figure 7. The steady state N^* has a zero shadow price of fish while $\hat{N}$ has a positive shadow price of fish and an equilibrium output below $\bar{Q}$. At $\hat{N}$ the rate of growth of fish equals the rate of interest, i.e., $1/\beta f'(\hat{N})=1$. Since f is concave, fish are a good investment if $N_0\in(0,\hat{N})$. Hence, starting from any point in

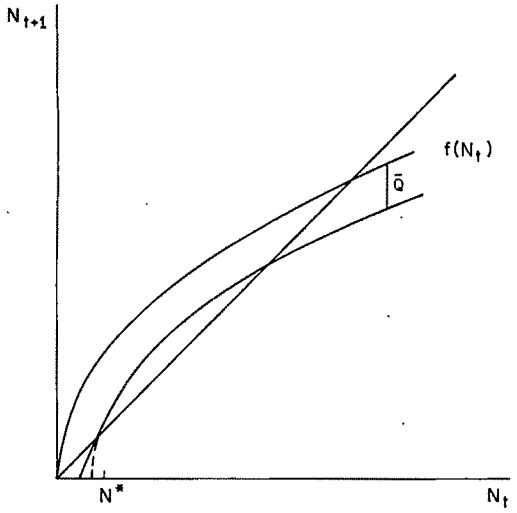

FIGURE 8

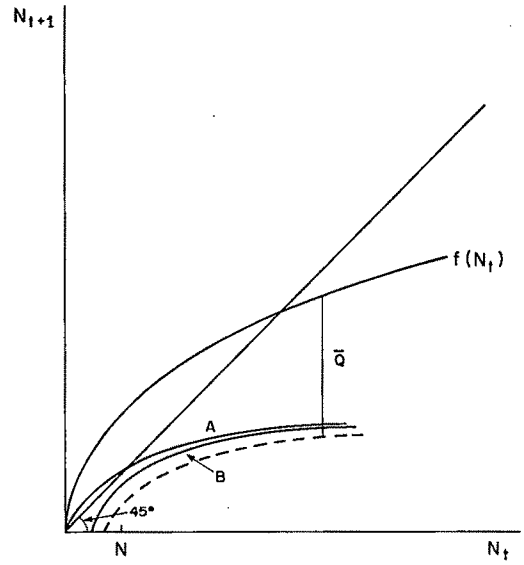

FIGURE 9

$(0, \hat{N})$ the stock of fish will grow to $\hat{N}$. If $N_0 \in (\hat{N}, N^*)$ fish are a poor investment, and the stock of fish will fall over time to $\hat{N}$. At and above N^* fish are a free good. Note that N^* is an unstable equilibrium. Above N^* the fish stock will grow to N^{**}.

Even if $\bar{Q}$ is sustainable it may be optimal to exhaust the stock of fish. Figure 8 depicts the situation in which extinction occurs in finite time as would be the case if $\pi'(0)<\infty$ and $1/\beta f'(0)>1$. If $\pi'(0)=+\infty$ extinction in finite time is not optimal, as would be the case in Figure 8 if the optimal dynamics touched the horizontal axis at the origin. Below N^* fish are a poor investment. Moreover extinction occurs more slowly than under free-entry competition (the dotted line in Figure 8). This situation was described in some detail above with the aid of Figure 6. Above N^* the fish stock is allowed to grow, since once again fishing rights are of no economic value.

There are several interesting situations which may arise if $\bar{Q}$ is not (even potentially) sustainable. For example if $1/\beta f'(0)>1$ and $\pi'(0)<\infty$, then extinction in finite time is optimal for *any* initial fish population, that is, $\bar{Q}$ is so large compared to all sustainable outputs that there is no region in which fishing rights are a free good. Since $1/\beta f'(0)>1$, fish are always a poor investment. Extinction does, however, proceed more slowly than under free-entry competition (the dotted line in Figure 9). Under the same conditions, except that $\pi'(0)=\infty$, extinction in finite time is not optimal. This would be the case in Figure 9 if curve B were to touch the horizontal axis at the origin.

Finally if $1/\beta f'(0)<1$, there is a region in which fish grow more rapidly than the rate of interest. If $\bar{Q}$ is larger than the maximum sustainable output, there is a unique stable equilibrium at $\hat{N}$, as depicted in Figure 9 (curve A). This is the only way for a nonzero steady state to exist when $\bar{Q}$ is not sustainable.

B. *The Optimum Path when Costs Depend upon the Size of the Stock of Fish*

In this section it is assumed that the size of the stock of fish affects the marginal cost function. Having demonstrated the relationship between a centrally planned solution and the competitive solution when fishing rights are owned, it is simplest to solve for the optimal path by formally solving the optimization problem for a central planner. The planning solution can be interpreted as a competitive equilibrium as was done in Part A above. Although we will solve the planner's problem, we will use the profit function notation.

Let $\pi(Q_t, f(N_{t-1})) \equiv \int_0^{Q_t}[D(s) - \tilde{C}'(s, f(N_{t-1}))]\,ds$ be the welfare function at time t. It is assumed that $\tilde{C}_1>0$, $\tilde{C}_2<0$, and $\tilde{C}_{12}<0$. The condition on the cross partial simply requires that marginal costs fall with an increase in stock size. It is also assumed that $\tilde{C}$ is a strictly convex function, so that π is strictly concave. The objective is to maximize the present value of welfare. The Lagrangian is given by

$$L=\sum_{t=1}^{\infty}\delta^{t-1}\big(\pi(Q_t, f(N_{t-1}))$$
$$+\lambda_t[f(N_{t-1})-N_t-Q_t]\big).$$

The first-order conditions are

$$\frac{\partial L}{\partial Q_t}: \pi_1(Q_t, f(N_{t-1}))-\lambda_t=0, \qquad t=0,1,\ldots$$

$$\frac{\partial L}{\partial N_t}: \delta\pi_2(Q_{t+1}, f(N_t))f'(N_t)$$
$$+\delta\lambda_{t+1}f'(N_t)-\lambda_t=0,$$
$$t=0,1,\ldots$$

Combining these equations yields

$$\delta\{\pi_2(Q_{t+1}, f(N_t))+\pi_1(Q_{t+1}, f(N_t))\}f'(N_t)$$
$$=\pi_1(Q_t, f(N_{t-1}))$$

$$\delta\left\{1+\frac{\pi_2(Q_{t+1}, f(N_t))}{\pi_1(Q_{t+1}, f(N_t))}\right\}f'(N_t)$$
$$=\frac{\pi_1(Q_t, f(N_{t-1}))}{\pi_1(Q_{t+1}, f(N_t))}$$

$$\left\{1+\frac{\Delta\lambda_t}{\lambda_t}\right\}\left\{1+\frac{\pi_2(Q_{t+1}, f(N_t))}{\pi_1(Q_{t+1}, f(N_t))}\right\}f'(N_t)$$
$$=1+r$$

where $\Delta\lambda_t=\lambda_{t+1}-\lambda_t$.

Several points are worthy of note. First, since $\pi_2>0$ for all N, fish are *always* valuable, so that $\lambda_t>0$ for all t. Let $\tilde{Q}_t$ be the catch in the case of free-entry competition.

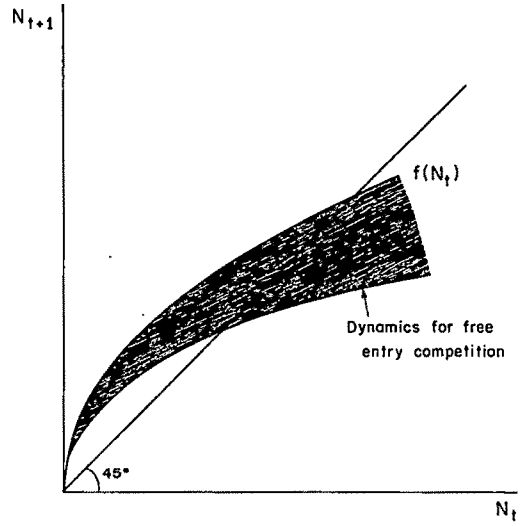

FIGURE 10

Then $\tilde{Q}_t$ satisfies the equation

$$\pi_1(\tilde{Q}_t, f(N_{t-1}))=0.$$

The optimal catch, Q_t, satisfies

$$\pi_1(Q_t, f(N_{t-1}))=\lambda_t>0.$$

Since π_1 is a decreasing function, the optimal catch for any given size of the stock of fish is smaller than the one which would occur under free-entry competition. This puts some restrictions on the optimal dynamics. Specifically, they must lie in the cross-hatched area in Figure 10.

This guarantees that some obvious restrictions will be met, such as

1) If free-entry competition does not result in the eventual extinction of the species, neither will the optimal path.

2) If free-entry competition results in a steady state to the right of $\tilde{N}$, which is defined by the equation $f'(\tilde{N})=1$, so will the optimal path.

The second point should, by now, be obvious. The optimal catch corresponds to a point where rates of return are equalized. In this case, though, there are three compounded rates of return from leaving a fish in the sea for an additional period. The

added term in this case

$$\left\{1+\frac{\pi_2(Q_{t+1}, f(N_t))}{\pi_1(Q_{t+1}, f(N_t))}\right\}$$

can be interpreted as a rate of return in terms of lowered costs. By leaving a fish in the sea, one has effectively invested π_1, the foregone profit which could be gained by selling the fish. In return, there will be a yield of π_2, the resulting increase in profits due to lower costs. Hence $\{1+\pi_2/\pi_1\}$ is the rate of return achieved by this investment. The value $\{1+\Delta\lambda_t/\lambda_t\}$ again measures the appreciation or depreciation, corresponding respectively to a shrinking or growing stock of fish. The stock, and output, will be growing if

$$\left\{1+\frac{\pi_2(Q_{t+1}, f(N_t))}{\pi_1(Q_{t+1}, f(N_t))}\right\}f'(N_t)>1+r$$

that is, if fish are a "good investment" and shrinking if

$$\left\{1+\frac{\pi_2(Q_{t+1}, f(N_t))}{\pi_1(Q_{t+1}, f(N_t))}\right\}f'(N_t)<1+r$$

that is, if fish are a "bad investment." The steady state occurs when $\lambda_t=\lambda_{t+1}$ or when

$$\left\{1+\frac{\pi_2(Q_{t+1}, f(N_t))}{\pi_1(Q_{t+1}, f(N_t))}\right\}f'(N_t)=1+r$$

Figure 6 is relevant here, as before. Since $\{1+\pi_2/\pi_1\}>1$, the steady state will have a larger stock of fish than would be the case if costs were *not* a function of the stock of fish; that is, if $\hat{N}$ solves $f'(\hat{N})=1+r$ and $\tilde{\tilde{N}}$ solves $\{1+\pi_2/\pi_1\}f'(\tilde{\tilde{N}})=1+r$. Then, $\tilde{\tilde{N}}>\hat{N}$.

Moreover, when costs are independent of the size of the stock of fish it is not possible to have more than one nonzero steady state in which fishing rights have a positive price since $f'(N)$ is a monotonically decreasing function of N. Hence there is at most one $\hat{N}$ satisfying $f'(\hat{N})=1+r$. However,

$$\left\{1+\frac{\pi_2[Q(N), f(N)]}{\pi_1[Q(N), f(N)]}\right\}f'(N)$$

is not necessarily a monotonic function of N, so that one cannot rule out the possibility of multiple steady states.

The question naturally arises whether or not anything may be said about the number and "location" of these steady states. It can be shown that there exists no more than one steady state to the right of $\tilde{N}$.

The proof is fairly straightforward. Consider

$$N_t=f(N_{t-1})-Q(N_{t-1})\equiv H(N_{t-1})$$

For there to be two steady states to the right of $\tilde{N}$, the slope of the optimal dynamics must be greater than one at one of these steady states, i.e., $H'(N_{t-1})$ would have to exceed 1. However, this is impossible since above $\tilde{N}$, $f'(N_{t-1})\leq 1$ and $Q'(N_{t-1})>0$ (which is shown in the Appendix) it follows that $H'(N_{t-1})=f'(N_{t-1})-Q'(N_{t-1})<1$.

This narrows the possibilities for multiple steady states rather drastically. All steady states must lie above $\hat{N}$ and there can be no more than one to the right of $\tilde{N}$.

In some real world situations it ought to be possible to determine that the optimal policy has a unique steady state to the right of $\tilde{N}$ on the basis of fairly crude information. For example, it is sufficient to know that

(a) Free-entry competition results in an equilibrium to the right of $\tilde{N}$, or

(b) $\pi_2[Q(N), f(N)]/\pi_1[Q(N), f(N)]>r$.

Each of these conditions is sufficient to guarantee the existence of a unique steady state.

The possible nonuniqueness of the steady state has struck some writers as an enigma. Yet there is nothing mysterious about it. Since it only occurs when $\pi_2/\pi_1<r$, it is a phenomenon associated with "costs that depend upon stock size, but not very much." Figure 7 shows how multiple steady states can occur when costs are independent of stock size. The possible existence of multiple steady states when costs are "almost" independent of stock size is quite compatible with our intuition that the optimal solution ought to depend in some continuous way on these costs.

Note also that in the case in which cost depends upon the size of the fish population, as before, it may be optimal to eventually

exhaust the resource. This will be the case if

$$\left\{1+\frac{\pi_2[Q(N), f(N)]}{\pi_1[Q(N), f(N)]}\right\}f'(N)<1+r$$

for all N less than or equal to N_0. The details are substantially the same as before, and will not be repeated.

APPENDIX

In this Appendix several facts will be derived about the dynamic programming problem. Define the value function

$$V(N)=\sup_{\{Q_t\}}\sum_{t=1}^{\infty}\delta^{t-1}\pi(Q_t, f(N_{t-1}))$$

subject to $Q_t+N_t=f(N_{t-1})$. It is assumed that π is strictly concave.

First note that V is concave. Let $\bar{N}$ and $\bar{\bar{N}}$ be two possible values of the initial fish population and let $\{\bar{Q}_t\}$ and $\{\bar{\bar{Q}}_t\}$ be the corresponding optimal policies. Then if the initial stock is $\lambda\bar{N}+(1-\lambda)\bar{\bar{N}}$, the policy $\lambda\bar{Q}_t+(1-\lambda)\bar{\bar{Q}}_t$ is feasible.

PROOF:

Let $N^*=\lambda\bar{N}+(1-\lambda)\bar{\bar{N}}$, and suppose that $N_t^*\geqslant\lambda\bar{N}_t+(1-\lambda)\bar{\bar{N}}_t$, then

$$\begin{aligned}N_{t+1}^*&=f(N_t^*)-\lambda\bar{Q}_{t+1}-(1-\lambda)\bar{\bar{Q}}_{t+1}\\&\geqslant f\left[\lambda\bar{N}_t+(1-\lambda)\bar{\bar{N}}_t\right]\\&\quad-\lambda\bar{Q}_{t+1}-(1-\lambda)\bar{\bar{Q}}_{t+1}[\text{since } f'>0]\\&\geqslant\lambda f(\bar{N}_t)+(1-\lambda)f(\bar{\bar{N}}_t)\\&\quad-\lambda\bar{Q}_{t+1}-(1-\lambda)\bar{\bar{Q}}_{t+1}[\text{since } f''<0]\\&=\lambda\bar{N}_{t+1}+(1-\lambda)\bar{\bar{N}}_{t+1}\end{aligned}$$

Hence by induction,

$$N_t^*\geqslant\lambda\bar{N}_t+(1-\lambda)\bar{\bar{N}}_t\geqslant 0,\qquad \text{for all } t$$

which is the property that ensures feasibility.

From this it follows that

$$\begin{aligned}&V\left(\lambda\bar{N}+(1-\lambda)\bar{\bar{N}}\right)\\&\quad\geqslant\sum_{t=1}^{\infty}\delta^{t-1}\pi\left[\lambda\bar{Q}_t+(1-\lambda)\bar{\bar{Q}}_t, f(N_{t-1}^*)\right]\\&(\text{by } f'\geqslant 0)\qquad\geqslant\sum_{t=1}^{\infty}\delta^{t-1}\pi\Big[\lambda\bar{Q}_t+(1-\lambda)\bar{\bar{Q}}_t,\\&\qquad f\left(\lambda\bar{N}_{t-1}+(1-\lambda)\bar{\bar{N}}_{t-1}\right)\Big]\\&(\text{by } f''<0)\qquad\geqslant\sum_{t=1}^{\infty}\delta^{t-1}\pi\Big[\lambda\bar{Q}_t+(1-\lambda)\bar{\bar{Q}}_t,\\&\qquad\lambda f(\bar{N}_{t-1})+(1-\lambda)f(\bar{\bar{N}}_{t-1})\Big]\\&(\text{by } \pi \text{ concave})\qquad\geqslant\lambda\sum_{t=1}^{\infty}\delta^{t-1}\pi\left[\bar{Q}_t, f(\bar{N}_{t-1})\right]\\&\qquad+(1-\lambda)\sum_{t=1}^{\infty}\delta^{t-1}\pi\left[\bar{\bar{Q}}_t, f(\bar{\bar{N}}_{t-1})\right]\\&\qquad=\lambda V(\bar{N})+(1-\lambda)V(\bar{\bar{N}})\end{aligned}$$

Since V is concave it is differentiable except perhaps at a countable number of points. Moreover it can be shown that V is in fact differentiable.

The value function can be put into the following dynamic programming formulation

$$\text{(A1)}\qquad V(N)=\max_{Q}\{\pi(Q, f(N))+\delta V(f(N)-Q)\}$$

Differentiating with respect to Q yields

$$\text{(A2)}\qquad \pi_1(Q, f(N))=\delta V'(f(N)-Q)$$

Equation (A2) yields an optimal harvest policy as a function of the stock, $Q=Q(N)$. Replacing the optimal value Q by $Q(N)$ in equation (A1) and differentiating with respect to N yields

$$\text{(A3)}\qquad V'(N)=\pi_2 f'+\delta V' f'.$$

Hence,

$$\text{(A4)} \quad V'(N_{t-1})=\pi_2 f'+\delta V'(N_t)f'.$$

This can be used to demonstrate the basic properties of the model. From (A2) and (A4), it follows that

$$V'(N_{t-1})-V'(N_t)=\pi_2 f'+\pi_1 f'-\pi_1/\delta$$

or

$$V'(N_{t-1})-V'(N_t)=\frac{\pi_1}{\delta}\left\{\delta f'\left[1+\frac{\pi_2}{\pi_1}\right]-1\right\}$$

Since $\pi_1/\delta>0$ it must be true that if $f'[1+\pi_2/\pi_1]>1+r, V'(N_{t-1})-V'(N_t)>0$, and by concavity $N_t>N_{t-1}$. Conversely, if $f'[1+\pi_2/\pi_1]<1+r, V'(N_{t-1})-V'(N_t)<0$ and so $N_t<N_{t-1}$.

It is easy to show that the function $Q(N)$ is increasing. Rewrite condition (A2) as

(A2′)

$$\pi_1[Q[N], f[N]]-\delta V'[f(N)-Q(N)]=0,$$

suppose that there exists an $N_1>N_0$ such that $Q(N_1)\leqslant Q(N_0)$, with $Q(N_0)>0$. Then

$$\pi_1[Q(N_0), f(N_0)]\leqslant\pi_1[Q(N_1), f(N_0)] <\pi_1[Q(N_1), f(N_1)]$$

and,

$$\delta V'[f(N_0)-Q(N_0)]\geqslant\delta V'[f(N_1)-Q(N_1)]$$

These conditions together imply that

$$\pi_1[Q(N_1), f(N_1)] -\delta V'[f(N_1)-Q(N_1)]>0$$

which is a contradiction. Hence Q is increasing.

This property implies that there can be no more than one steady state to the right of $f'=1$. The dynamics of the problem are

$$N_t=f(N_{t-1})-Q(N_{t-1})\equiv H(N_{t-1})$$

Hence as long as $Q'>0$, $H'<1$ whenever $f'\leqslant 1$.

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Exact Consumer's Surplus and Deadweight Loss

By JERRY A. HAUSMAN*

Consumer's surplus is a widely used tool in applied welfare economics. Both economic theorists and cost benefit analysis often use consumer's surplus despite its somewhat dubious reputation. The basic idea is to evaluate the value to a consumer or his "willingness to pay" for a change in price of a good from say price p^0 to price p^1. Because price changes affect consumer welfare, an evaluation of this effect is often a key input to public policy decisions. Yet consumer's surplus is probably the most controversial of widely used economic concepts. Both Paul Samuelson and Ian Little conclude that the economics profession would be better off without it.

It is my feeling of the situation that substantial agreement exists on the correct quantities to be measured: the amount the consumer would pay or would need to be paid to be just as well off after the price change as he was before the price change. The quantities correspond to John Hicks' compensating variation measures. An alternative measure which takes *ex post* price change utility as the basis of comparison is Hicks' equivalent variation.[1] The controversy arises in the measurement of these quantities. The usual measurement procedure is to use the area to the left of the Marshallian (market) demand curve between two price levels. Jules Dupuit originated this measure of welfare change, and Alfred Marshall and Hicks derived appropriate conditions for its use. The primary condition for the area to the left of the demand curve to correspond to the compensating variation is to have constant marginal utility of income. Marshall gave this condition, and if it holds, the same quantity will be derived as the area to the left of the compensated (Hicksian) demand curve. This area to the left of the compensated demand curve is exactly what the compensating variation and equivalent variation measure. Thus the constant marginal utility of income is a sufficient condition for Marshallian consumer's surplus to be equal to Hicks' consumer's surplus. In this case Arnold Harberger's plea to use the welfare triangle as one-half times the product of the price change times the quantity change to measure deadweight loss corresponds to the correct theoretical amount of welfare change.

In a recent paper, Robert Willig derives bounds for the percentage difference between the correct measure of either the compensating or equivalent variation and the Marshallian measure derived form the market demand curve. His bounds, which depend on the income elasticity of demand for the single good in the region of price change being considered as well as the proportion of the consumer's income spent on the good, demonstrate that the Marshallian consumer's surplus is often a good approximation to Hicks' consumer's surplus. The fact that the proportion of the consumer's income spent matters as well as the income elasticity was first pointed out by Harold Hotelling. Willig contends that the approximation error will be less than the errors involved in estimating the demand curve. Thus he hopes to remove the need for apology that applied economists often need to give to theorists who remark on the inappropriateness of using Marshallian consumer's surplus to measure welfare change.

However, in this paper I show that for the case primarily considered by Willig of a single price change, which is also the situation in which consumer's surplus is often used in applied work, no approximation is necessary.

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[1]The reason that we still have two, rather than one, of Samuelson's six measures of consumer's surplus arises from an index number problem of the correct basis for the welfare comparison. I will give both measures but plan to concentrate on the compensating variation.

From an estimate of the demand curve, we can derive a measure of the *exact* consumer's surplus, whether it is the compensating variation, equivalent variation, or some measure of utility change. No approximation is involved. While this result has been known for a long time by economic theorists, applied economists have only a limited awareness of its application. Furthermore, for the majority of cases the calculations are simple enough for a hand calculator. It seems preferable to remove completely any approximation argument from so important a matter as consumer's surplus. Also, my exact formulae allow calculation of the precision of our estimated consumer's surplus in terms of a standard error of estimation. Since unknown parameters for the demand curve will usually be estimated by econometric procedures, standard error formulae allow construction of confidence regions for the estimated compensated variation. These confidence regions might well be an important input to policy decisions. In most empirical applications we would like to account for the error in estimating the demand curve rather than including it in the approximation error as Willig implicitly does. Lastly, for some important uses of consumer's surplus, Willig's approximation argument is not useful. For instance, in assessing the welfare loss from taxation of labor income or capital income the proportion of total income can become so large that the Marshallian measure could differ markedly form the Hicks' measure of compensating variation or equivalent variation.[2]

However, a more important shortcoming of the use of the Marshallian measure (and Willig's approximation argument) arises in measuring deadweight loss. Here we are not interested in the complete compensating variation, which is a trapezoid to the left of the appropriate demand curve, but rather the triangle which corresponds to the excess of the compensating variation over the tax revenue collected from an individual. This triangle corresponds to the welfare measure that Harberger has used in his many studies of the effect of taxation on the U.S. economy. Even in cases where Willig's approximations hold for the complete compensating variation, the Marshallian deadweight loss can be a very poor approximation for the theoretically correct Hicksian measure of deadweight loss based on the compensated demand curve. Thus the Marshallian measure of deadweight loss is not accurate for the important measurements often undertaken in applied welfare economics and public finance studies. But, again, given an estimate of the uncompensated demand curve we can derive the exact measure of deadweight loss. As the example in the concluding section of the paper shows, the traditional measurement of the welfare triangle can lead to badly biased estimates of the true deadweight loss even when the conditions for Willig's approximation argument hold true for measurement of consumer's surplus.

The basic idea used in deriving the exact measure of consumer's surplus is to use the *observed* market demand curve to derive the *unobserved* compensated demand curve. It is this latter demand curve which leads to the compensating variation and equivalent variation.[3] In the two-good case using modern duality theory, I begin with the market demand curve and derive the corresponding indirect utility function. These two functions permit exact calculation of the compensating variation, equivalent variation and deadweight loss. In the many-good case when a single price changes, I derive the "quasi" indirect utility function and the "quasi" expenditure function. I denote the appropriate functions as quasi since they do not corre-

[2]For recent uses of consumer's surplus in these situations, see Michael Boskin and Martin Feldstein. Many important applications in public finance have the feature that a large proportion of an individual's income is involved.

[3]Hal Varian derives the compensating variation as the area under the Hicksian compensated demand curve. He then remarks that "unfortunately, since the Hicksian demand curves are unobservable these expressions do not appear to be useful" (p. 210). Herbert Mohring considers the properties of different welfare measures and uses a technique similar to mine to derive the compensating variation for the Cobb-Douglas case. G. W. McKenzie and I. F. Pearce and Y. O. Vartia use somewhat similar approaches but use different methods of analysis.

spond exactly to the individual's indirect utility function and expenditure function. To derive these functions, one would require estimates of the complete system of demand equations. The complete demand system usually cannot be estimated due to lack of data. Instead, I use Hicks' aggregation theorem to demonstrate that the quasi functions which correspond to the assumption of a two-good world would give exactly the same measure of consumer's surplus as the actual functions for a single price change. Thus, the estimates of the uncompensated demand curve are all that is required to produce estimates which correspond to the correct theoretical magnitude.

My approach differs from much recent work in that I begin with the observed market demand curve and then derive the unobserved indirect utility function and expenditure function. The more common approach is to start from a specification of the utility function, for example, Stone-Geary or translog, and then estimate the unknown parameters from the derived market demand functions. The method used here seems preferable on two grounds. First, the only observable data are the market demand data so good econometric practice would indicate finding a function that fits the data well. Thus, different specifications of the demand curve, not the utility function, would be fit with the best-fitting demand equation chosen to base the applied welfare analysis on. Second, specifications such as the translog functions force all the demand curves to have the same functional form which are often difficult to fit econometrically. Since here I consider only partial-equilibrium welfare analysis, I need only estimate a single demand function. Again, alternative specifications of the demand curve allow consideration of the robustness of the results to the chosen specification. The demand curve approach offers considerably more flexibility than does the utility function approach in obtaining good econometric results given the available market data.

In the next section, I derive the indirect utility function and expenditure function for the two-good case. It is shown how the use of these functions leads to correct measure of the compensating variation and equivalent variation. Section II then extends the analysis to the many-good case when only one price changes. There I show that the two-good analysis can be applied with only slight modifications. The functions for the case of a general quadratic demand curve are also derived. Lastly, in Section III, I provide an example of labor supply where the Marshallian approximation is inaccurate for the true compensating variation. I also provide an example of the calculation of deadweight loss to demonstrate that even when the Marshallian measure of the compensating variation is reasonably accurate, the Marshallian measure of deadweight loss can be incorrect by a relatively large amount. Section IV provides a brief conclusion to the paper.

I. The Compensating Variation and Equivalent Variation in the Two-Good Case

The basic tools which I will use in the analysis emerge from the dual approach to consumer behavior. The conventional treatment of consumer behavior considers the maximization of a strictly quasi-concave utility function defined over n goods, $x=(x_1,\ldots,x_n)$, subject to a budget constraint.

$$(1)\quad \max_x u(x) \text{ subject to } \sum_{i=1}^{n} p_i x_i = p\cdot x \leqslant y$$

where p_i are prices and y is (nonlabor) income.[4] The dual approach to the problem is to consider the associated minimization problem which defines the expenditure function

$$(2)\quad e(p,\bar{u}) \equiv \min_x p\cdot x \text{ subject to } u(x) \geqslant \bar{u}$$

The expenditure function was introduced into the literature by Lionel McKenzie; for recent

[4]Local nonsatiation will be assumed throughout the analysis so that the budget constraint will hold as an equality.

analysis and applications see Leo Hurwicz and Hirofumi Uzawa and Peter Diamond and Daniel McFadden. Charles Blackorby and W. Erwin Diewert have recently studied local properties of the expenditure function. The important property of the expenditure function which we will find extremely useful is that the partial derivative with respect to the jth price gives the Hicksian compensated demand curves.[5]

$$(3) \qquad \frac{\partial e(p,\bar{u})}{\partial p_j} = h_j(p,\bar{u})$$

These unobservable Hicksian demand curves should be distinguished from the observable market uncompensated demand curves $x(p, y)$. At an optimum solution to equations (1) and (2) the demands coincide at maximum utility u^*, $h(p, u^*) = x(p, y)$.

The other function we will use which connects the utility function of equation (1) and the expenditure function of equation (2) is the indirect utility function which is the solution to the maximization problem

$$(4) \qquad v(p,y) \equiv max\,[u(x): p\cdot x \leqslant y]$$

Properties of the indirect utility function are derived in Diewert. An important property of the indirect utility function which we will use is René Roy's identity which yields the observed market demand curves as partial derivatives of $v(p, y)$.

$$(5) \qquad x_j(p,y) = -\partial v(p,y)/\partial p_j / \partial v(p,y)/\partial y$$

It is the difference between equation (3) for the compensated demand curve and equation (5) for the uncompensated demand curve that induces the difference between Marshallian consumer's surplus and exact Hicks' consumer's surplus when a price change occurs. Since the indirect utility function of equation (4) is monotonically increasing in income while the expenditure function of equation (2) is monotonically increasing in utility, either function can be inverted to derive the other corresponding function.

Let us now consider a change in the price vector from p^0 to p^1 and formally define the exact measures of consumer's surplus, the compensating variation, and equivalent variation, using the expenditure function.[6] Holding nonlabor income constant at y^0, the compensating variation $CV\ (p^0, p^1, y^0)$ is the minimum quantity required to keep the consumer as well off as he was in the initial state characterized by (p^0, y^0) as he is in the new state $(p^1, y^0 + CV)$. In terms of the expenditure function

$$(6) \qquad CV(p^0,p^1,y^0) = e(p^1,u^0) - e(p^0,u^0) = e(p^1,u^0) - y^0$$

where $u^0 = v(p^0, y^0)$ from the indirect utility function. Equivalently the compensating variation can be defined through the indirect utility function as $v(p^1, y^0 + CV) = v(p^0, y^0)$. An alternative measure of welfare change is the equivalent variation, $EV(p^0, p^1, y^0)$, which uses utility after the price change as the basis of comparison:[7]

$$(7) \qquad EV(p^0,p^1,y^0) = e(p^1,u^1) - e(p^0,u^1)$$

Using either the compensating variation or equivalent variation, it can be shown that the area under the compensated Hicksian demand curve corresponds to consumer's surplus.

[5]The other useful property of the expenditure function which will be utilized in subsequent analysis is that the second derivatives of the expenditure function yield the elements of the Slutsky matrix $S_{ij} = \partial^2 e(p;\bar{u})/\partial p_i \partial p_j = \partial h_j(p,\bar{u})/\partial p_i$.

[6]Willig and Avinash Dixit and P. A. Weller do a similar derivation.

[7]The compensating variation and equivalent variation always have the same sign because of the monotonicity of $e(p, u)$ in prices so long as the net demands do not change sign. Except for the single price change case, no inequality relationship holds in general.

Let us consider the case when only the first price changes from p_1^0 to p_1^1 with all other prices held constant. Equation (3) gives the compensated demand curve, and integrating it between the two price levels gives

$$(8)\quad CV(p^0, p^1, y^0) = e(p^1, u^0) - e(p^0, u^0)$$

$$= \int_{p_1^0}^{p_1^1} h_1(p, u^0)\,dp_1 = \int_{p_1^0}^{p_1^1} \frac{\partial e(p, u^0)}{\partial p_1}\,dp_1$$

The equivalent variation is derived in an identical manner where u^0 is replaced by u^1.[8]

Let us now compare this measure of welfare change with the traditional measure of Marshallian consumer's surplus as the area under the uncompensated demand curve of equation (5).[9] The integral has the form

$$(9)\quad A(p^0, p^1, y^0) = \int_{p_1^0}^{p_1^1} x_1(p, y^0)\,dp_1$$

$$= -\int_{p_1^0}^{p_1^1} \frac{\partial v(p, y^0)/\partial p_1}{\partial v(p, y^0)/\partial y}\,dp_1$$

This integral in general differs from the integral for the compensating variation in equation (8). To keep the individual on the same indifference curve, y^0 which enters both the numerator and denominator of equation (9) must be constantly adjusted along the path of the price change. Since y^0 is kept constant, this produces the difference between the uncompensated market demand curve with its Marshallian measure of consumer's surplus and the compensated demand curve with its measure of the compensating variation.

It is the supposed constancy or near constancy of the marginal utility of income which has often served as a basis for using Marshallian consumer's surplus as a measure of welfare change. However, equations (6) and (9) in general do not give the same measure. The difference between the compensated Hicksian demand curve which forms the basis for equation (6) and the uncompensated Marshallian demand curve which forms the basis for equation (9) follows from Slutsky's equation

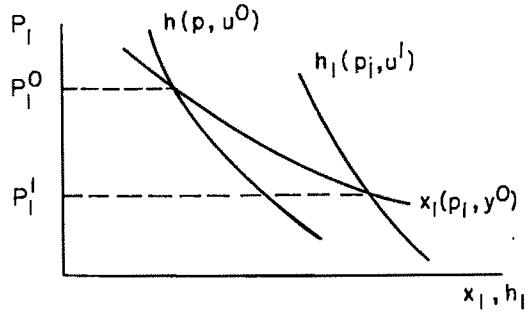

FIGURE 1

$$(10)\quad \frac{\partial h_1(p, u^0)}{\partial p_1} - \frac{\partial x_1(p, y^0)}{\partial p_1} = x_1 \cdot \frac{\partial x_1(p, y^0)}{\partial y}$$

A sufficient condition for equation (10) to equal zero is that both $\partial^2 v(p, y^0)/\partial y \partial p$ and $\partial^2 v(p, y^0)/\partial y^2$ equal zero. These conditions correspond to the case of constant marginal utility of income. For the case of a normal good, the compensated demand curve has steeper slope than the market demand curve so Figure 1 demonstrates the inequalities for a single price change $EV(p^0, p^1, y^0) \leq A(p^0, p^1, y^0) \leq CV(p^0, p^1, y^0)$, an inequality found in Willig. His paper shows that even when the marginal utility of income is not constant that the percentage difference, $(CV - A)/A$, is not large under certain conditions.

Let us now turn to the empirical application of consumer's surplus. It turns out that for many applications no approximation is needed since equation (6) or (7) can be computed exactly. I begin with the simplest case, two goods only with prices $p^0 = (p^0, 1)$. Thus I use the second good as numeraire and consider a price change to p_1^1. Both the price of the first good and income are normalized with respect to the price of the second good,

[8]An alternative but equivalent method of interpreting our procedure is to use equation (3) to write $\partial e/\partial p_j = h_j(p, \bar{u}) = x_j(p, e(p, \bar{u}))$. In principle this implicit equation can always be numerically integrated from p^0 to p^1 to find the exact compensating variation. Vartia gives a computer algorithm for the numerical integration method. My technique to find closed-form solutions uses Roy's identity to derive a differential equation which can be explicitly solved in many cases.

[9]Varian (pp. 209 ff.) does a similar analysis.

which does not change. While this case is very simple, it is not totally unrealistic. It is often used in empirical analysis, especially when a separability assumption between the good whose price changes and the other goods is appropriate. A very general treatment of separability is contained in Blackorby, Primont, and Russell, but for use herein, a simple interpretation of separability which allows us to write the utility function of equation (1) as $u(x_1,\ldots,x_n)=u(x_1, g(x_2,\ldots,x_n))$ is adequate. The appropriate price index which corresponds to the structure of $u(\cdot)$ provides the numeraire good. Separability of the indirect utility function is defined in an analogous manner, $v(p_1, k(p_2,\ldots,p_n)$ where $k(\cdot)$ provides the price index. In general separability of $u(\cdot)$ does not imply separability of $v(\cdot)$ or vice versa.

Separability utility functions justify specification and estimation of demand curves that have only a single price in them. An important example often used in empirical studies is the linear labor supply relationship

$$(11)\quad x_j=\alpha w_j+\delta y_j+z_j\gamma+\varepsilon_j;\quad j=1,\ldots,J$$

estimated over a sample of J individuals where w_j is the commodity price deflated (net after tax) wage, y_j is the commodity price deflated nonlabor income, Z_j is a vector of socioeconomic characteristics, and ε_j is a stochastic disturbance. Numerous other commodity demand equations are specified in this form where the wage is replaced by the price of the commodity.

To derive the exact compensating variation is straightforward and provides an exact welfare measure. The basic idea is to take the *observed* market demand curve and to use Roy's identity from equation (5) to integrate and derive the indirect utility function.[10] Inversion of the indirect utility gives the expenditure function which allows calculation of the compensating variation. Equivalently, using equation (3) we can derive the *unobservable* compensated demand curve. And equation (8) shows that the area under the compensated demand curve yields the exact consumer's surplus.

In principle we can always perform this integration for a well-specified demand function. This statement is the essence of the famous integrability problem in consumer demand.[11] So long as the derivatives of the *compensated* demand functions satisfy the properties of symmetry and negative semidefiniteness of the Slutsky matrix and the adding-up condition, the indirect utility function can be recovered by integration.[12] In practice, many commonly used demand functions in empirical work yield explicit solutions so that exact welfare analysis is easily done.

Returning to the two-good example, consider the nonstochastic demand function (where both p_1 and y are deflated by the price of the other good, p_2):[13]

$$(12)\quad x_1=\alpha p_1+\delta y+z\gamma$$

$$=-\partial v(p_1,y)/\partial p_1/\partial v(p_1,y)/\partial y$$

I solve this linear partial differential equation by applying the method of characteristic curves which assures a unique solution, given an initial condition.[14] To make welfare comparisons we will want to be on a given indifference curve. As the price changes I will use the equation $v(p_1(t), y(t))=u_0$ for some u_0; for example, initial utility in the compensat-

[10]This technique has been used in estimating demand with nonlinear budget constraints by Gary Burtless and myself, and in my earlier article.

[11]See Samuelson and Hurwicz and Uzawa.

[12]In addition a regularity condition is needed. A Lipschitz-type condition is given by Hurwicz and Uzawa. A stronger sufficient condition that often holds is for the demand function to be continuously differentiable.

[13]It has been pointed out to me by Diewert that this demand specification corresponds to a flexible functional form for the underlying preferences as discussed in Blackorby and Diewert. Basically, three independent parameters are needed for the demand function in the two-good case, which equation (12) has, so that the value of demand, the uncompensated price derivative, and the income derivative can attain arbitrary values.

[14]See Fritz John or Richard Courant and David Hilbert. Given that along an initial curve (here an indifference curve), the initial values are continuously differentiable then a unique solution to the partial differential equation exists.

ing variation case. Along a path of price change to stay on the indifference curve, we have

$$(13)\quad \frac{\partial v(p_1(t), y(t))}{\partial p_1(t)}\frac{dp_1(t)}{dt} + \frac{\partial v(p_1(t), y(t))}{\partial y(t)}\frac{dy(t)}{dt}=0$$

Then, using the implicit function theorem and Roy's identity from equation (12),

$$(14)\quad \frac{dy(p_1)}{dp_1}=\alpha p_1+\delta y+z\gamma$$

I have now expressed y as a function of p_1 and can solve the ordinary differential equation (14) to find

$$(15)\quad y(p_1)=c\,e^{\delta p_1}-\frac{1}{\delta}\left(\alpha p_1+\frac{\alpha}{\delta}+z\gamma\right)$$

where c, the constant of integration, depends on the initial utility level u_0. In fact, I simply choose $c=u_0$ as our cardinal utility index. Therefore, solving equation (15), we find the indirect utility function[15]

(16)

$$v(p_1, y)=c=e^{-\delta p_1}\left[y+\frac{1}{\delta}\left(\alpha p_1+\frac{\alpha}{\delta}+z\gamma\right)\right]$$

Then the corresponding expenditure function (again normalized by the price of the second good) follows simply from equation (16) by interchanging the utility level with the income variable

$$(17)\quad e(p_1, \bar{u})=e^{\delta p_1}\bar{u}-\frac{1}{\delta}\left(\alpha p_1+\frac{\alpha}{\delta}+z\gamma\right)$$

It is important to note that this procedure yields a *local solution* to the differential equation over some domain in price space. It is not always the case that there exists a global solution to equation (12) which satisfies the integrability conditions. However, we need only a local solution to make the welfare calculations that we are interested in. That is, we only want to compute a welfare measure at two price points, sat p_1^0 and p_1^1, which equations (16) and (17) permit us to do.

We now have a solution to Roy's identity, but we need to check whether we have a valid indirect utility function which arises from consumer maximization.[16] The indirect utility function of equation (16) is continuous and homogeneous of degree zero in prices and income by my normalization condition using p_2 as numeraire. It is also decreasing in prices if $\alpha\leqslant 0$ and increasing in income if $\delta\geqslant 0$. The other condition $v(p_1, y)$ must satisfy is quasi concavity which is equivalent to the Slutsky condition

$$(18)\quad s_{11}=\frac{\partial h_1(p_1, \bar{u})}{\partial p_1} =\alpha+\delta(\alpha p_1+\delta y+z\gamma)\leqslant 0$$

where the compensated demand curve $h_1(p_1, \bar{u})$ follows from the expenditure function of equation (17) by differentiation with respect to p_1. So long as the sign conditions are satisfied by the demand function we can calculate exact consumer's surplus and deadweight loss using the expenditure function of equation (17) and indirect utility function of equation (16).

To compute the compensating variation we use equation (17) and equation (6) to find

$$(19)\quad CV(p_1^0, p_1^1, y_0) =e^{\delta(p_1^1-p_1^0)}\left[y_0+\frac{1}{\delta}\left(z\gamma+\frac{\alpha}{\delta}+\alpha p_1^0\right)\right] -\frac{1}{\delta}\left(z\gamma+\frac{\alpha}{\delta}+\alpha p_1^1\right)-y^0 =\frac{1}{\delta}e^{\delta(p_1^1-p_1^0)}\left[x_1^0(p_1^0\cdot y_0)+\frac{\alpha}{\delta}\right] -\frac{1}{\delta}\left[x_1^1(p_1^1\cdot y^0)+\frac{\alpha}{\delta}\right]$$

[15]Any monotonic transformation of this equation will of course satisfy the differential equation since ordinal utility is determined only up to a monotonic transformation. The only change would be in c, the constant of integration.

[16]Diewert discusses the appropriate conditions.

This expression for the compensating variation, while certainly more complicated than the Marshallian triangle formula, is still straightforward to calculate. The corresponding equivalent variation would be calculated from equation (7). Furthermore, since the parameters for equation (17) are presumably estimated by econometric methods, well-known methods allow calculation of the large sample standard error for the compensating variation in equation (19) (for example, see Rao, p. 323). Note, also that the compensating variation now varies across individuals by their socioeconomic characteristics and their income levels while the corresponding Marshallian expressions neglects these factors in its approximation. Use of the compensating variation or equivalent variation ends all arguments about the appropriateness of the Marshallian approximation since they give the exact measure of welfare change.

Another commonly used demand curve specification in the two-good case is the constant elasticity specification[17]

$$(20)\quad x_1 = e^{z\gamma} p_1^{\alpha} y^{\delta} = -\partial v(p_1, y)/\partial p_1 / \partial v(p_1, y)/\partial y \qquad \delta \neq 1$$

which is often estimated in *log*-linear form as $\log x_{1j} = z_j\gamma + \alpha \log p_{1j} + \delta \log y_j + \varepsilon_j$ for $j = 1, \ldots, J$.[18] To find the indirect utility function we use the technique of separation of variables and integrate to find

$$(21)\quad v(p_1, y) = c = -e^{z\gamma} \cdot \frac{p_1^{1+\alpha}}{1+\alpha} + \frac{y^{1-\delta}}{1-\delta}$$

where c, the constant of integration, has again been set at the initial utility level. The Slutsky condition is $s_{11} = x_1(\alpha/p_1 + \delta x_1/y)$. The expenditure function (again normalized by p_2) is

$$(22)\quad e(p_1, \bar{u}) = \left[(1-\delta)\left(\bar{u} + e^{z\gamma}\frac{p_1^{1+\alpha}}{1+\alpha}\right)\right]^{1/1-\delta}$$

so that the compensating variation for a change in price from p_1^0 to p_1^1 is the quantity

$$(23)\quad CV(p_1^0, p_1^1, y^0) = \left\{(1-\delta)\left[\frac{e^{z\gamma}}{1+\alpha}\left(p_1^{1\ 1+\alpha} - p_1^{0\ 1+\alpha}\right)\right] + y^{0(1-\delta)}\right\}^{1/1-\delta} - y^0$$

$$= \left\{\frac{(1-\delta)}{(1+\alpha)y^{0\delta}}\left[p_1^1 x_1^1(p_1^1, y^0) - p_1^0 x_1^0(p_1^0, y^0)\right] + y^{0(1-\delta)}\right\}^{1/1-\delta} - y^0$$

Again an exact formula for the compensating variation is derived for which a standard error could be straightforwardly calculated given a covariance matrix for the estimated parameters. No approximation argument is required in using the compensating variation as a measure of welfare change. It is interesting to note that while the denominator of equation (9) is constant for the demand specification of equation (20) so that in this case the Marshallian area also gives an exact measure of welfare change, it is not equal to either the compensating variation or the equivalent variation. The income effect from equation (10) is not zero so that the compensated demand derivative and uncompensated demand derivative differ by a positive amount. Thus, use of the Marshallian measure still involves an error of approximation if either the compensating variation or the equivalent variation are the desired measure.

II. The Many-Good Case and More General Demand Specifications

The welfare measures developed at the beginning of Section I were all fully general in the sense that they considered n different

[17]Again this demand curve provides a flexible functional form for the underlying preferences.

[18]Willig considers a constant income elasticity demand specification in deriving his approximations. For $\delta = 1$ the indirect utility function has the same form as equation (19) except that the last term is replaced by $\log y$.

goods and allowed all n prices to change. In particular, the compensating variation of equation (6) and the equivalent variation of equation (7) used the expenditure function whose arguments are the complete price vector and the appropriate utility level. In this section I generalize the methods of calculating the compensating variation to the many-good case but continue to consider only one price change.[19] While we cannot recover the complete expenditure function as before, we can still recover the quasi-expenditure function whose derivative yields the appropriate compensated demand curve. Thus again the compensating variation and equivalent variation can be estimated exactly given information on the market demand curve for the good whose price has changed.

A complete specification of a system of demand equations would have the general form

$$(24) \quad x_i = x(p, y, z, \varepsilon_i); \qquad i=1,\ldots,N$$

where p is the price vector, z is a vector of socioeconomic characteristics, and ε_i is a stochastic disturbance. So long as the estimated coefficients of the demand system have the property that the Slutsky matrix is symmetric and negative semidefinite and that the function $x(\cdot)$ is regular in p and y, then in principle the system can be integrated and the expenditure functions derived. However, the usual case is that we do not have information on all quantity demands at the individual level. But suppose we do have information on demand for, say, the first good whose price is expected to change as a result of the public policy measure being considered. A first-order Taylor expansion of equation (24) would lead to the econometric specification[20]

$$(25) \quad x_1(p, y) = z\gamma + \sum_{i=2}^{N} \frac{\delta_i y}{p_i} + \sum_{i=2}^{N} \frac{\alpha_i p_1}{p_i} + \varepsilon_1$$

[19]The one-price-change situation is the case considered by Willig.

[20]I am indebted to Diewert for help in improving this section of the paper from an earlier version.

The important point to note about equation (25) is that by assumption only p_1 will change due to the contemplated policy measure, while z, y, and $p_2,\ldots,p_n$ will remain constant. Thus, all prices except the first can be written as a scalar multiple of a price index, $p_2=\lambda_2 q,\ldots,p_N=\lambda_N q$ where $\lambda_2,\ldots,\lambda_N$ are known fixed positive constants. We can now apply Hicks' composite commodity theorem.[21] Rewrite equation (25) as

$$(26) \quad x_1(p_1, q, y)$$
$$= z\gamma + \left(\sum_{i=2}^{N} \frac{\delta_i}{\lambda_i}\right)\frac{y}{q} + \left(\sum_{i=2}^{N} \frac{\alpha_i}{\lambda_i}\right)\frac{p_1}{q}$$
$$= z\gamma + \delta\frac{y}{q} + \alpha\frac{p_1}{q}$$

where $\delta = \sum_{i=2}^{N} \delta_i/\lambda_i$ and $\alpha = \sum_{i=2}^{N} \alpha_i/\lambda_i$

Since equation (26) is the same as equation (12) except that the composite price q has replaced p_2, I can repeat the analysis of the last section with the welfare analysis based on equations (16) and (17). Note that the resulting functions might best be referred to as a quasi-indirect utility function and a quasi-expenditure function. We have not recovered the complete indirect utility function or expenditure function, but the "quasi" functions lead to exact welfare measures when all other prices are constant. But they cannot be used to analyze the welfare change when more than one price changes (except proportionately) without further analysis.

Let us now briefly consider some extensions of our techniques to more general cases. First, we can generalize the *log*-linear demand specification of equation (20) to the many good consumer,

$$(27) \quad x_1(p, y) = e^{z\gamma} \prod_{i=2}^{N} \left(\frac{p_1}{p_i}\right)^{\alpha_i} \prod_{i=2}^{N} \left(\frac{y}{p_i}\right)^{\delta_i}$$

[21]For other references and developments of this theorem, see Terrance Gorman and Blackorby et al. and Diewert.

Again, if only the first price changes, we can obtain the quasi-expenditure function corresponding to equation (22) by the application of Hicks' composite commodity theorem to obtain

$$(28)\quad x_1(p_1, q, y) = e^{z\gamma}\left(\frac{p_1}{q}\right)^{\sum_{i=2}^{N}\alpha_i}\left(\frac{y}{q}\right)^{\sum_{i=2}^{N}\delta_i}$$

Use of the quasi-expenditure function allows exact welfare measures to be calculated.

I now return to the two-good case to present some generalizations of the demand specification with the observation that they can be expanded to the N good case by the techniques which lead to equations (26) and (28). Thus, I again normalize by the second price so that p_1 and y are divided by p_2. I return to the linear demand specification of equation (12) but allow the price and income coefficients of the demand specification, as well as the intercept, to depend on individual socioeconomic characteristics. Let $\delta = zd$ and $\alpha = za$ which leads to the demand specification[22]

$$(29)\quad x_1(p_1, y) = z\gamma + zdy + zap_1 + \varepsilon_1$$

Calculation of the welfare measures proceeds in the same way except that δ and α vary across individuals. Perhaps a more important generalization is to allow interactions among the price terms to move away from the linear demand curve specification. A demand function quadratic in prices is

$$(30)\quad x_1(p_1, y) = z\gamma + \delta y + \beta_1 p_1 + \beta_2 p_1^2 + \varepsilon_1$$

so long as the Slutsky term is negative we can integrate the corresponding differential equation by parts to find the indirect utility function

$$(31)\quad v(p_1, y) = e^{-\delta p_1}\left[y + a_1 p_1 + a_2 p_1^2 + a_3\right]$$

where $a_1 = \beta_1/\delta + 2\beta_2/\delta^2$, $a_2 = \beta_2/\delta$, and $a_3 = z\gamma/\delta + 2\beta_2/\delta^3$. With equation (31) exact welfare analysis is again straightforward since the expenditure function, compensating variation, and equivalent variation all follow from equation (31).

The last and most general demand curve that is considered is fully quadratic in both prices and income. The demand function is

$$(32)\quad x_1 = \beta_0 + \beta_1 y + \beta_2 p_1 + \beta_3 y^2 + \beta_4 p_1^2 + \beta_5 p_1 y + \varepsilon_1$$

where $\beta_0 = z\gamma$. Using Roy's identity we have the nonlinear differential equation

$$(33)\quad \frac{dy}{dp_1} + Qy + Ry^2 + S = 0$$

where $R = -\beta_3$, $Q = -(\beta_1 + \beta_5 p_1)$ and $S = -(\beta_0 + \beta_2 p_1 + \beta_4 p_1^2)$. It turns out that this equation can be transformed by changes of variables to the famous Schrodinger wave equation of physics. I give the derivation in the Appendix where the indirect utility function is found to have the form

$$(34)\quad v(p, y) = \left(h\tilde{W}_1 - \tilde{W}_1^1\right)/\left(\tilde{W}_2^1 - h\tilde{W}_2\right)$$

where $h = -\beta_3 y + (\beta_5/2)(\beta_1 + \beta_5 p)^2$ and $\tilde{W}_1$ and $\tilde{W}_2$, functions of the β parameters of equation (32) and prices, which are straightforward to calculate. Their exact form is given in the Appendix. Again, the expenditure function and exact welfare measures follow directly from equation (34). Thus, we have a very general demand specification with associated exact welfare measures. In fact, the demand function may well provide a third-order flexible function form in the sense of Blackorby and Diewert.

III. Calculation of the Compensating Variation and of the Deadweight Loss

In the previous section, I have given formulae for calculating the exact welfare change by deriving the unobservable compensated demand curve given market information. Here I consider two examples to demonstrate use of the formulae. I can also assess how accurate the Marshallian ap-

[22]Stochastic terms can be added of the type $\delta = Zd + v$, which lead to a random coefficients specification. The resulting heteroscedasticity can be accounted for in the estimation procedure. This type of demand function is estimated in my article with Burtless.

proximations are for the exact welfare measures. The first example of labor supply shows that the approximation may be quite poor for goods which form a large proportion of total expenditure. Since Willig showed that the approximation might not do well in this case, the finding is not surprising. However, the second example raises severe doubt about the use of uncompensated market demand for a commodity which is only a small proportion of the budget when we calculate the deadweight loss from the imposition of a tax. Even though the conditions for an accurate approximation to the compensating variation hold, the approximation to the deadweight loss is very inaccurate. In fact, this finding seems to hold in general. While the Marshallian approximation is adequate in certain situations for the compensating variation, it is often *not* accurate under these conditions for measurement of the deadweight loss. Since measurement of the deadweight loss is often the goal in applied welfare economics, this finding strongly recommends use of the exact measure deadweight rather than the Marshallian approximation.

The first example used, is a linear labor supply function of the form of equation (11). The estimates used are taken from a study of wives' labor supply functions in my forthcoming paper. The estimated values used for the jth individual are

$$(35) \quad h_j = 495.1w_j - .1250y_j + 765.1$$

The left-hand side variable is hours per year of work, w_j is market wage which has a mean of \$4.15 per hour, y_j is after tax income of the husband which has a mean of \$8,236, and the constant takes account of demographic factors such as age and children.

Here I calculate the required compensating variation after the imposition of a 20 percent proportional tax on labor earnings. Compared to a no-tax situation, the expenditure takes the form

$$(36) \quad e(w,\bar{u}) = e^{-\delta w}\bar{u} - \frac{\alpha}{\delta}w + \frac{\alpha}{\delta^2} - \frac{z\gamma}{\delta}$$

Calculating u^0 from the corresponding indirect utility function and using it in equation (36) leads to a required expenditure of \$9485 per year. I find that the compensating variation is \$2,056. Using the formula for distribution of a nonlinear function, I find one standard error for the compensating variation to be plus or minus \$481. Then to find the aggregate compensating variation for the complete population, a sample enumeration would be done allowing the wages, husband's income, and socioeconomic variables to differ across individuals.

Calculations of the Marshallian approximation is straightforward since we use the estimates of equation (35) and measure the area to the left of the labor supply curve between the initial and final net wages of \$4.15 per hour and \$3.32 per hour. The Marshallian approximation is \$1,315 per year so that the two measures differ by 44.6 percent. Thus, the Marshallian measure provides a very poor approximation to the exact measure of welfare change. That the Marshallian measure provides a poor approximation in this case is in line with Willig's results since the Marshallian area is large with respect to base income. Hence, the Taylor approximation which provides Willig's bounds demonstrates that the derivation between the two measures can be substantial. It is worth emphasizing again that the exact welfare change is easily calculated from the indirect utility function and the expenditure function. Then no worry about the accuracy of the approximation is needed.

The last example I consider is the more important one, since it involves a quite common use of consumer's surplus in applied welfare economics. I consider the deadweight loss from imposition of a commodity tax.

Consider the compensated demand curve $h(p, u_0)$ shown in Figure 2. The compensating variation is the area to the left of the demand curve between the initial price p^0 and the final, post tax, price p^1. But we are often *more* interested in the welfare triangle which measures the efficiency loss from the use of distorting taxes. This triangle corresponds to the Harberger measure. Therefore, I define the deadweight loss to be the difference of the compensating variation minus

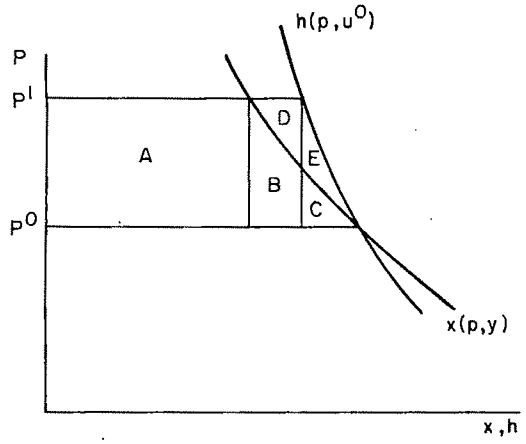

FIGURE 2

the tax revenue collected. The rectangle in Figure 2 thus has only distributional consequences while the triangle is the deadweight burden which cannot be undone. Optimal tax policy typically tries to minimize the sum of the deadweight losses to achieve a second best optimum, for example, see Diamond and Mirrlees.

The particular example I consider is meant to approximate the long-run demand for gasoline, although the numbers used are hypothetical. The demand function is

$$(37) \qquad q_j = -14.22p + .082y_j + 4.95$$

Choosing income for the mean person to be \$720 per month and initial price to be \$.75 per gallon, the price elasticity is .2 with an income elasticity of 1.1. Both elasticities are similar to elasticities which have been found in empirical studies. Let us now consider imposition of a tax which raises the price of gasoline to \$1.50 per gallon. Using equation (17) we find that the compensating variation equals \$37.17 per month. The Marshallian approximation equals \$35.99 per month, so that the two measures differ by only 3.2 percent. Thus, the Willig results are confirmed since demand for gasoline is only a small part of the total budget for the individual.

However, when we compare the two measures of deadweight loss we find a substantial difference. The compensated measure of the deadweight loss is \$2.88 while the Marshallian measure is \$3.96. The two measures differ by 31.7 percent, even though the approximation is good for the compensating variation. Why can the approximation be so poor for the deadweight loss? Using order arguments somewhat loosely, the compensating variation is composed of two pieces, the rectangle which is a first-order quantity of demand times change in price while the deadweight loss is a second-order quantity of one-half the changes in demand times the change in price. While the Marshallian approximation does reasonably well for the first-order part of the compensating variation under certain conditions given by Willig, its performance on the second order part may still be quite bad.

In Figure 2 we see that both measures of the compensating variation have rectangle A in common, which is a large part of the whole. In measuring the first-order effect they differ only by triangle D, which is small compared to the whole. However, in measuring the deadweight loss, the percentage difference will depend on the difference of area B and triangle E compared to the area of triangle C. Figure 2 shows that this difference can often be substantial. Thus, the Marshallian approximation is not accurate for measurement of the deadweight loss. Instead, the exact Hicksian measure should be used. While the Willig results will hold for the compensating variation, if the goal of the calculation is deadweight loss, the Marshallian approximation should not be used. In many cases it is a very inaccurate measure of the true deadweight loss.

IV. Conclusion

In empirical situations where a measure of either the compensating variation, equivalent variation, or deadweight loss is needed, economists often work with relatively simple demand specifications. For these types of specifications we have developed the exact measures of welfare change. While it has been known that use of the compensated demand curves lead to the appropriate welfare measures, it has not been generally recognized how straightforward it is to de-

rive the compensated demand curves from observed market demand curves. I derived methods which are easily applied to the two-good case. These methods are then extended to the many-good case with one price change. The quasi-indirect utility function and expenditure function provide the appropriate compensated demand curve and thus the appropriate welfare measure. While our measures tell us the appropriate compensation, they, of course, do not necessarily give the correct measurement of the loss in social welfare if no compensation is paid.

Through two examples I attempt to assess the accuracy of the Marshallian approximation. For a good which forms a small part of the total budget, the Marshallian area is reasonably accurate as proven by Willig. But if the good forms a large part of the budget, the approximation may be quite inaccurate as our labor supply example shows. A more important finding is the high level of inaccuracy when the deadweight loss, or welfare triangle, is measured. For deadweight loss, the Marshallian area can often be quite far off even though it is reasonably accurate for the compensating variation in the same situation. The gasoline example shows that the deadweight loss measures differ by 32 percent even though the compensating variation measures differ by 3.2 percent. Thus, it seems *inappropriate* to measure deadweight loss by using the market demand curve. But since the exact deadweight loss measure can be often calculated by use of the compensated demand curve, no special problem arises. The formulae given in this paper permit exact calculation of both the compensating variation and of the deadweight loss.

APPENDIX

Let us consider derivation of the indirect utility function and expenditure function which corresponds to the fully quadratic demand curve of Section II.[23]

The demand function that I consider is

$$x_1=\beta_0+\beta_1 y+\beta_2 p_1+\beta_3 y^2+\beta_4 p_1^2 + \beta_5 p_1 y+\varepsilon_1$$

where $\beta_0=Z\gamma$. Using Roy's identity this demand equation may be written as the nonlinear differential equation

$$y'+Qy+Ry^2+S=0$$

where $R=-\beta_3$, $Q=-(\beta_1+\beta_5 p_1)$ and $S=-(\beta_0+\beta_2 p_1+\beta_4 p_1^2)$. I do one change of dependent variable $y=(1/R)(u'/u)$ and one change of independent variable $t=\beta_1+\beta_5 p_1$ calling the resulting function $\phi(t)$ to find

$$\phi''+\beta_5 t\phi'+q\phi=0$$

where $q=\beta_5^2 SR$. Thus, I have transformed the nonlinear equation, a Ricatti equation, to a second-order differential equation of the form studied by physicists. I then transform by $W=\phi e^{\beta_5 t^2/4}$ to put the equation in parabolic cylinder form $W''+WM=0$ where $M=\delta_0+\delta_1 t+\delta_2 t^2$ and the δ_i's are easily calculated functions of the β_i's. I have thus transformed the original equation into the famous Schrodinger wave equation. One last change of independent variable $x^2=4(\delta_1 t+\delta_2 t^2)$ and we have the final form

$$W''+W\left(\delta_0+\left(x^2/4\right)\right)=0.$$

Define the functions $W_1=1+\delta_0(x^2/2)+(\delta_0^2-(1/2)(x^4/4!)+\ldots$ and $W_2=x+\delta_0(x^3/3!)+(\delta_0^2-3/2)(x^5/5!)+\ldots$, which converge quickly for values likely to be encountered in economics.[24] Now define $\gamma_0=\delta_1\beta_1+\delta_2\beta_1^2$, $\gamma_2=\delta_1\beta_5+2\delta_2\beta_1\beta_5$, and $\gamma_3=\delta_2\beta_5^2$ and we have the W_i function in terms of prices $\tilde{W}_1=1+2\delta_0(\gamma_1+\gamma_2 p_1+\gamma_3 p_1^2)+(2/3)(\delta_0^2-1/2)(\gamma_1+\gamma_2 p_1+\gamma_3 p_1^2)^2+\ldots$ and $\tilde{W}_2=2\delta_0(\gamma_2+2\gamma_3 p_1)+(1/3)(\delta_0^2-1/2)(\gamma_1+\gamma_2 p_1+\gamma_3 p_1^2)(\gamma_2+2\gamma_3 p_1)+\ldots$ which again converge

[23] Generalization to the many-good case is straightforward. Only a sketch of the derivation is provided here. Further details may be obtained by writing the author.

[24] Description and analysis of the parabolic cylinder functions is found in Milton Abramowitz and Irene Stegum (ch. 19). The successive coefficients of the expansion have a simple recursive formula which eases calculation.

quickly. The indirect utility function thus takes the form

$$\text{(A1)} \qquad v(p, y) = \frac{h\tilde{W}_1 - \tilde{W}_1'}{\tilde{W}_2' - h\tilde{W}_2}$$

where $h = -\beta_3 y + \beta_5 t^2/2$. The expenditure function also takes a simple form in terms of the W functions

$$\text{(A2)} \quad e(p_1, \bar{u}) = \frac{t\beta_5^2}{2\beta_3} - \frac{1}{\beta_3}\left(\frac{\tilde{W}_1' + \bar{u}\tilde{W}_2'}{\tilde{W}_1 + \bar{u}\tilde{W}_2}\right)$$

Then equation (A1) is used to compute utility at original prices p_1^0 and equation (A2) is used to compute $e(p_1^1, \bar{u})$ so that after subtracting off y_0 we find the compensating variation. The W functions are straightforward to calculate and both tables and computer routines exist to do the calculation.

I might note that it is straightforward to generate demand functions and corresponding indirect utility functions and expenditure functions that are closed form and contain quadratic terms in both prices and incomes. But I have not yet found demand functions of this type which can be estimated using linear regression techniques. The specification leading to (A1) and (A2) has this advantage although specialized computer routines then become necessary to evaluate the consumer's surplus and deadweight loss measures.

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Corporate Tax Integration in the United States: A General Equilibrium Approach

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This paper presents estimates of static and dynamic general equilibrium resource allocation effects for four alternative plans for corporate and personal income tax integration in the United States. A medium-scale numerical general equilibrium model is used which integrates the *U.S.* tax system with consumer demand behavior by household and producer behavior by industry.

Results indicate that total integration of personal and corporate taxes would yield an annual static efficiency gain of around $6 billion (1973 dollars). Partial integration plans yield less. Dynamic effects are larger, and our analysis indicates that full integration may yield gains whose present value is as large as $500 billion or about 1.0 percent of the discounted present value of the *GNP* stream to the *U.S.* economy after correction for population growth. Plans differ in their distributional impacts, although these findings depend on the nature of replacement taxes used to preserve government revenues. The size of dynamic resource allocation effects is sensitive to the choice of the replacement tax, while static gains are reasonably robust.

I. The Taxation of Corporate Income

A corporate tax which operates separately from the personal income tax is widely acknowledged to lead to a number of problems. It creates a "double" taxation of corporate income. Dividends are paid out of net of corporate tax profits and are further taxed under the personal income tax. Retained earnings, to the extent they are capitalized in higher share values, are also taxed twice, although only fractionally and on a deferred basis by the personal income tax. This double taxation may reduce overall rates of return and adversely affect capital accumulation. A second problem is often referred to as the "lock-in" effect. The efficiency of capital markets is impaired due to the deferral advantage given to retained earnings; firms can reinvest retained earnings in projects with a low yield and their shareholders can still earn a higher net of tax return than if the funds were distributed as dividends and reinvested elsewhere. Thirdly, since only equity returns are subject to corporate taxes, there is a bias towards debt finance, potentially distorting corporate financial policies. Finally, the corporate tax introduces higher effective tax rates in some industries than others, due to special provisions in the corporate tax law and to the varying degrees to which industries are incorporated. These tax rate differentials further disrupt an efficient allocation of capital.[1] Integration plans seek to remove or mitigate these features by linking personal income tax liabilities of stockholders (either on dividends or on all earnings) to the corporate tax liabilities of the firms.

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[1]The competitive model implies net of tax rates of return on capital are equalized across industry. In a situation where capital tax rates vary by industry, this equalization requires that the gross marginal productivity of capital differ among the industries. The efficiency gain accomplished by reducing the differential capital tax rates is due to the reallocation of capital towards industries where it is more productive.

A variety of plans have been proposed over the years, but these typically move only part way to a full integration of personal and corporate taxation. The common objective of all these tax integration plans is to improve the efficiency of the economy through beneficial resource reallocation, in both a static and a dynamic sense. In this paper, four corporate tax integration alternatives are considered. The plans differ in the extent to which they remove the undesirable features of the present corporate income tax.

Plan 1: *Total Integration*: Under this alternative, the corporate income tax is eliminated, and the personal income tax is modified to tax total shareholder earnings, rather than just dividends. When capital gains are realized, the tax basis is set at the original purchase price plus the retained earnings accumulated during the holding period. This feature avoids a double tax on retained earnings capitalized in higher stock prices. However, if the basis is not reset for inflation, the base for capital gains tax will include pure nominal appreciation. This amounts to a capital wealth levy. We evaluate this partnership integration plan with and without inflation indexation of capital gains. These total integration plans are the most comprehensive we consider. They contain modifications to the income tax which, if they had originally been made, would have dispensed with the need for a separate corporate tax. Industrial distortions through the corporate tax are removed, as is the corporate tax distortion of intertemporal consumption choice.

Plan 2: *Dividend Deduction from Corporate Income Tax Base*: This approach simply removes the "double" taxation of dividends by making them deductible from taxable corporate income. Capital gains taxation of individuals is unaltered, and the corporate income tax is effectively converted into a tax on retained earnings only. If current differences in retention policies by industry remain, then some industrial discrimination would continue within the corporate tax.

Plan 3: *Dividend Deduction from Personal Income Tax Base*: An alternative way of removing double taxation of dividends is to allow a dividend deduction from the personal income tax rather than from the corporate income tax. Capital gains taxation is again unaltered. Under this plan, all corporate earnings are taxed at the corporate tax rate, and none are taxed at the personal income tax rate. As with Plan 2, under different retention policies by industry, some industrial discrimination will remain under the corporate tax.

Plan 4: *Dividend "Gross Up"*: This was the plan most actively discussed in the *U.S.* tax reform debate during 1977. It seeks to reduce rather than remove the double taxation of dividends. Part of the income tax paid by corporations is given as an income tax credit to stockholders when dividends are distributed.[2] The credit is taxable, hence the description gross up. Because of the partial nature of the credit, none of the distortions listed above can be wholly removed.

II. A General Equilibrium Model of the U.S. Economy and Tax System

The implementation of an integration plan results in changes in all relative prices in the economy due to the realignment of industry tax rates; both short- and long-run equilibrium quantities will also change. Intertemporal decisions will be reevaluated with a changed rate of return to capital, and the division of time between labor and leisure will be altered. The relative positions of groups within the household sector will change, and therefore a complete evaluation of integration plans should incorporate the interacting nature of the efficiency and distributional effects involved. While a new post-integration tax system may involve uniform tax rates and may be easy to evaluate, the existing tax system is nonuniform. Implementation of any corporate tax integration plan will result in a new set of effective tax rates on capital income by industry and on personal income by consumer groups, and all equilibrium prices and quantities can be expected to vary; the direct effects intended from an integration plan can be offset or

[2]A 15 percent credit was often mentioned and is modeled here. A further possibility discussed was that differential credits might be given depending on the industry in which a company operates; this is not modelled.

TABLE 1—CLASSIFICATION OF INDUSTRIES, CONSUMER EXPENDITURES, AND CONSUMER GROUPS IN THE MODEL

Industries	Consumer Expenditures
1. Agriculture, Forestry, and Fisheries	1. Food
2. Mining	2. Alcoholic Beverages
3. Crude Petroleum and Gas	3. Tobacco
4. Contract Construction	4. Utilities
5. Food and Tobacco	5. Housing
6. Textiles, Apparel, Leather Products	6. Furnishings
7. Paper and Printing	7. Appliances
8. Petroleum Refining	8. Clothing and Jewelry
9. Chemicals and Rubber	9. Transportation
10. Lumber, Furniture, Stone	10. Motor Vehicles, Tires, and Auto Repair
11. Metals, Machinery, Miscellaneous Manufacturing	11. Services
12. Transportation Equipment	12. Financial Services
13. Motor Vehicles	13. Reading, Recreation, misc.
14. Transportation, Communications, and Utilities	14. Nondurable-Nonfood Household Items
15. Trade	15. Gasoline and Other Fuels
16. Finance and Insurance	16. Savings
17. Real Estate	
18. Services	
19. Government Enterprise	

Consumer Groups
(Households classified by $thousands of 1973 gross income)

1. 0-3	5. 6-7	9. 12-15
2. 3-4	6. 7-8	10. 15-20
3. 4-5	7. 8-10	11. 20-25
4. 5-6	8. 10-12	12. 25+

reinforced by induced changes in economic behavior.

Because these induced effects are multiple, nonmarginal, and interlinking, general equilibrium analysis is a natural technique to use in evaluating the combination of distributional and efficiency changes. A medium-size general equilibrium model of the *U.S* economy and tax system, estimated using 1973 data, is used to analyze the four corporate and personal income tax integration plans. It combines a treatment of the *U.S.* tax system with competitive consumer and producer behavior. Equilibrium prices and quantities are determined under each integration plan, and the effects of alternative taxation regimes are evaluated. The model is capable of analyzing the impacts of many different tax proposals concerning not only corporate taxes, but also income, Social Security, sales, property, and other taxes. It incorporates a labor-leisure choice, savings and investment, foreign trade, and government purchase policies. The full range of taxes currently operating in the United States is incorporated into the model. Both single period and multiperiod behavior can be considered. In dynamic analyses, a sequence of single period equilibria is computed, with capital stocks and labor supply changing over time. A labor force growth rate of approximately 2.75 percent per year in efficiency units is used. The precise number is chosen so as to guarantee that the *U.S.* economy is on an assumed balanced growth path in terms of the 1973 data we use. Savings decisions in each period are based on myopic expectations on the rate of return to capital; only in a steady state are these expectations correct.

Nineteen producer good industries, sixteen consumer expenditure items, and twelve consumer types classified by income range are identified and shown in Table 1. These dimensions are governed by a tradeoff between

model complexity, data availability, and computational expense. Capital and labor services are the primary factor inputs used by industry, and these are owned by consumer groups in different proportions. These two factors are mobile between industries, and their use is dictated by the zero-profit conditions of perfectly competitive markets.[3] Over time the capital service endowment can grow through investment, and the labor service endowment changes through labor force growth. A labor-leisure choice for households also enters the model. More details on the structure and specification of the model and its data are given in our 1979 article.

A. *Data Sources and Procedures*

The model requires the assembly of a comprehensive and consistent micro-economic data set. Such a data set has not been constructed before for the United States, but is essential for general equilibrium analysis of taxation policy.[4] This data set provides information on factor use by industry (and taxes paid for these), intermediate use of products, outputs of both producer and consumer goods, purchases of consumer goods by household types, incomes by source and by household type, income taxes paid, and several other items such as business investment and foreign trade. The complete 1973 data set used to calibrate the model is derived from five major sources. These include the July 1976 *Survey of Current Business*, unpublished worksheets of the U.S. Commerce Department's National Income Division, the Commerce Department's Bureau of Economic Analysis Input/Output tables, the U.S. Labor Department's 1973 Consumer Expenditure Survey, and the U.S. Treasury Department's merged tax file.

Inconsistencies between these data sets and general equilibrium conditions are resolved using systematic adjustment procedures described in Fullerton, Shoven, and Whalley. Effective tax rates and parameters for equations in the model are estimated from the benchmark equilibrium data set so as to replicate the consistent 1973 data base. Economic effects of each tax policy proposal are then estimated by changing the tax rates and recalculating a simulated equilibrium.

B. *Production*

Each industry produces a single producer good from a combination of capital services, labor services, and the outputs of other industries. Factor-input decisions are assumed to be made on the basis of cost minimization, and these decisions are affected by the tax system since taxes alter the relative producer prices of inputs for each industry.

The use of primary factors by each industry is described by a separate Constant Elasticity of Substitution (*CES*) or Cobb-Douglas production function. The model embodies a capability for preselection of functional form in addition to selection of parameter values. The intermediate use of products by industries is described by a conventional fixed coefficient input-output matrix. This matrix is derived from published 1970 input-output data for the United States and updated to 1973. No substitution between primary factors and intermediate inputs is permitted.

A number of "legal" taxation instruments are treated as production taxes and directly affect costs of industries. The corporate income tax, corporate franchise tax, and the property tax are in combination treated as *ad valorem* taxes on the use of capital services. The Social Security tax, unemployment insurance taxes, and public workmen's compensation taxes are treated as *ad valorem* taxes on the use of labor services. It is, of course, debatable whether these treatments are appropriate. Some recent literature argues for treating the Social Security tax as a benefit-related contribution and for treating the corporate income tax as a lump sum tax or as a tax on the use of equity instruments.

[3]Future extensions of this approach could disaggregate labor into skill types since these might have different rates of substitution for capital. Similarly, capital could eventually be broken down into land, equipment and structures, or some other useful definitions.

[4]Earlier data sets of this type for the United Kingdom have been used by Whalley, and by Piggott and Whalley.

TABLE 2—U.S. TAXES AND THEIR TREATMENT IN THE MODEL

Tax	Treatment in the Model	Difficulties of Model Treatment
1. Corporate taxes (including state and local) and corporate franchise taxes	*Ad valorem* tax on use of capital services by industry	Some argue for treatment as a lump sum tax; model treatment ignores role of financial instruments
2. Property taxes	*Ad valorem* tax on use of capital services by industry	Differential rates across jurisdictions ignored
3. Social Security taxes, Unemployment Insurance and Workman's Compensation	*Ad valorem* tax on use of labor services by industry	Benefit-related nature of contributions; arbitrary distinction between public and private insurance programs
4. Motor vehicles tax	*Ad valorem* tax on use of motor vehicles by producers	In practice, a yearly registration fee and not a purchase tax; averaging over jurisdictions
5. Retail sales tax	*Ad valorem* taxes on purchase of consumer goods	Averaging of rates over states
6. Excise taxes	*Ad valorem* taxes on output of producer goods	Taxes often expressed as charge per unit physical measure such as volume
7. Other indirect business taxes and nontax payments to government	*Ad valorem* tax on output of producer goods	Payments depend on output levels by industry to only limited extent; averaging of rates over states
8. Personal income taxes (including state and local)	Linear function for each consumer where tax on capital affects industry allocation	Detailed deductions and exemptions not specifically considered in model

Our model abstracts from these controversies, but we are aware of them.

In addition to taxes on the use of primary factors, the model includes taxes on the intermediate use of producer goods by industry and taxes on outputs of producer goods. Intermediate input taxes include the registration fees paid on motor vehicles for business use; producer output taxes include the federal manufacturers' excise taxes, paid on purchases for intermediate or final use. Table 2 describes the detailed treatment of all these taxes along with an outline of the entire *U.S.* tax system.

C. *Consumption*

Within the personal sector, twelve consumer groups are identified by their family gross of tax income as reported in the 1973 Consumer Expenditure Survey data published by the U.S. Department of Labor. The number of groups is restricted in order to keep the model of manageable size, but other consumer groupings could be considered. Additional characteristics, such as family size, age, marital status of household heads, and regional location could be examined, as done by J. R. Piggott and Whalley in their model of the *U.K.* tax system.

The income of each consumer group in any period is determined by the ownership of labor and capital services and receipt of transfer income, such as Social Security payments, from the government. Demands for the consumer goods, savings, and leisure are assumed to be generated by utility maximization subject to the household budget constraint.

The nested utility function is given by

$$U\left(H\left(\prod_{i=1}^{15} X_i^{\lambda_i}, L\right), C_f\right) \tag{1}$$

where H is a *CES* function determining the allocation of current expenditures between consumption goods X_i and leisure L, while the purchase decisions on the X_i are determined by a Cobb-Douglas subutility

function as shown. The elasticity of labor supply with respect to the real after tax wage is set at +0.15 (see H. Gregg Lewis). U is another *CES* function, determining the allocation of income between those current expenditures and expected future consumption C_f. The demand for C_f results in a derived demand for savings, where the elasticity of savings with respect to the real net-of-tax rate of return is taken as .4, consistent with the recent estimates by Michael Boskin.

Demands for the nineteen producer goods are derived from the demands for the sixteen consumer expenditure items using a "Z" transition matrix. An element z_{ij} of this matrix is the amount of producer good i needed to produce one unit of consumer expenditure item j. The distinction we make between producer and consumer goods enables us to simultaneously use national accounts data on a producer good classification and the recently released 1972–73 Consumer Expenditure Survey defined for consumer goods. The Z transition matrix solves the problem of distinguishing consumer demands for outputs of the trade and transportation industries from the demands for goods purchased at retail. Each consumer good requires some trade and transportation for its production. It also solves the problem of rare consumer purchases of goods such as "mining" output.

The sixteenth consumer expenditure item is savings, and the Z matrix permits us to treat it like other goods. We assume that the demand for savings depends upon the current rate of return on capital, given by the current price of capital services relative to the purchase price of new capital goods.[5] We thus assume myopic expectations in the sense that the current rental and purchase price of capital is expected to prevail in all future periods. Actual patterns of investment good purchases are the basis for constructing the column of the transition matrix which converts the consumer's demand for savings into demands for producer goods. This treatment assumes an equality between savings and investment. Savings of one period result in an equiproportional increase in the capital service endowment of households, where the conversion between net investment and capital service units uses a real net-of-tax rate of return of 4 percent.

Progressive personal income taxes are incorporated by a sequence of linear tax functions, one for each consumer. With an intercept that is usually negative and a marginal tax rate applied to all income, we can replicate observed 1973 tax payments and still subject income changes to the appropriate marginal rate. State and local income taxes are modelled as "piggyback" or percentage surcharge taxes applied to the federal levy.

Treatment of personal income taxes is complicated by the need to recognize the preferential treatment of certain types of capital income. Corporate retained earnings which are converted to capital gains have a lower present value tax liability than do earnings paid as dividends. Similarly, the extent to which capital earnings are sheltered by the unincorporated Investment Tax Credit will differ by industry. Thus, the effective personal income tax rate on capital income will differ by industry. Later we discuss the procedure used to introduce these preferential tax rates on some personal capital income, and we discuss their treatment in our modeling of the integration plans.

Government purchases are derived from a Cobb-Douglas demand function defined over producer goods. Government real expenditures are assumed to equal tax receipts less transfers since the general equilibrium approach requires that the government budget must be balanced. The foreign trade sector receives a simple treatment in order to close the model. By assuming that the net value of exports less imports for each producer good remains constant, we can calculate the net quantity transactions at any given vector of

[5]In order to capture the tax exempt nature of saving through pensions, Keogh plans, Individual Retirement Accounts, and life insurance, we model a 30 percent savings subsidy within the income tax framework. This proportion reflects data from *Flow of Funds* accounts. Another 20 percent of savings through owner occupied housing is also taxed on an expenditure tax basis, indicating that the United States is approximately halfway between income and expenditure taxation. Housing tax preferences are also captured by the model as discussed below.

producer prices and transform domestic demands to market demands.

III. Corporate Financial Policies and the Lock-In Effect

There are two important aspects of corporate tax integration which our model does not directly consider, although we have made some efforts to examine the sensitivity of our findings to alternative assumptions on these issues. One problem is the role of corporate financial policies and the other is the so-called lock-in effect.

In recent years a number of authors (Joseph Stiglitz, 1973, 1976; Mervyn King) have emphasized a view of the corporate tax as a differential tax on the various financial instruments available for transferring capital income from firms to individuals. Under this view, there are three different instruments through which capital income of corporations can be "paid" to the owners of capital: interest payments, dividends, and retentions which are assumed to be converted into capital gains. Each of these instruments has tax and nontax advantages and disadvantages that govern its relative use by industry. The firm which uses debt finance can deduct interest from its corporate tax base. This tax advantage is counteracted by the disadvantage that a heavily debt-financed company has a higher probability of bankruptcy and/or takeover. Equity financing cannot avoid corporate taxation, but may result in a large reduction in personal taxes if earnings are retained. Alternatively, though they have no tax advantage, dividends may be paid for a variety of other reasons.

For the purposes of the present paper, the important point is that with changes in tax law, firms can be expected to modify their financial policies. For example, if Plan 2 (dividend deduction from the corporate tax) encourages firms to pay out all earnings in dividends, then Plan 1 (total integration) and Plan 2 are identical in their effects.

We lack good estimates of financial policy elasticity parameters. Therefore, we examine various extreme behavioral reactions and calculate the effects of the tax change, given the assumptions involved. We thus cannot claim a "true" general equilibrium treatment of corporate financial policies since adjustments are made to the dividend/retention ratio to estimate model equivalent tax rates before we make our general equilibrium calculation.

With the lock-in effect, the issue is that the deferral advantage under the existing personal and corporate tax structure gives a tax preference to retention by existing firms. New firms entering financial markets must borrow at higher interest rates than those at which existing firms can implicitly borrow through retentions. Thus, if existing firms are slower growing and less efficient, the proper reallocation of resources to new firms may not take place.

Since we consider a general equilibrium model with constant returns to scale technology, we do not incorporate an explicit theory of individual firm behavior, and a reallocation of capital between firms within an industry does not affect the industry production function. We are therefore unable to incorporate efficiency aspects of the lock-in effect.

The resource allocation effects of corporate and personal tax integration we consider are restricted to interindustry and intertemporal distortions. Interindustry distortions enter through differential capital income tax rates by industry, and intertemporal distortions affect savings behavior in the economy and change capital allocation over time.

IV. Representing the Tax Integration Plans in Model Equivalent Form

Each of the tax integration plans described in Section I is represented in model equivalent form for the purposes of analyzing its general equilibrium impacts. For each plan we calculate a new set of appropriate effective tax rates and use these to compute a simulated equilibrium. We compare the new simulated equilibrium with the data generated by the model under a situation of no policy change.

We first calculate each industry's capital income net of corporate income tax, corporate franchise tax, and property tax. For each of the twelve consumer classes, data on

marginal tax rates (τ_j) are obtained from the Treasury Department's merged tax file. A weighted average marginal tax rate (τ) is calculated.

For each type of capital income, we define a single parameter g which reflects the proportion of that type of capital income which is fully taxed under the personal income tax. Interest and monetary rent are fully taxed by the personal income tax, so the g_I for interest and the g_{MR} for monetary rent are set to one. For the housing industry, imputed rent from owner-occupied homes is not taxable and has a g_{IR} of zero. For dividends in 1973, the government's revenue loss due to the $100 dividend exclusion from the personal income tax was estimated at $285 million.[6] We divide this by τ to get an estimate of nontaxable dividends, $1164 million. Since total dividends paid is $24,631 million, the proportion taxable is 0.96 and this figure is used as the g applied to dividends, g_D.

In the case of capital gains, Martin Bailey has shown that close to one-half of long-term capital gains are realized in a relatively short period, while the remainder is held for lengthier periods, averaging perhaps 35 years or more. Weighing the advantages of exclusion and deferral in light of these observations on holding periods leads to a conclusion that about 25 percent of nominal capital gains are effectively included in the base of the personal income tax. Accounting for 1973 inflation, however, we calculate that 73 percent of real capital gains in 1973 were fully taxed at the personal level, implying .73 as our g for retained earnings, g_{RE}.

The noncorporate investment tax credit ($NCITC$) also reduces the proportion g_{NC} of noncorporate capital income (NCI) which is effectively fully taxed by the personal income tax. For each industry, it is the dollar amount ($NCI-NCITC/\tau$) which is fully taxed at rate τ and yields observed tax payments ($\tau \cdot NCI-NCITC$).

Then, for each of the nineteen industries and government, we use the g proportions to define a fraction f_i, which denotes the proportion of that sector's capital income which is subject to full personal income taxation. The f_i fraction differs across industries for a number of reasons, but primarily because of different dividend and retention policies. In fact, to calculate the f_i, we make use of data on capital income types by industry, examining corporate profits (dividends and retained earnings), net interest payments (monetary and imputed), net rent payments (monetary and imputed), and the return to capital used in noncorporate business. An industry's f_i is the weighted average of the g proportions. Each industry has different weights which are its amounts of the various capital income types.

The average fraction of capital in all industries which is fully taxable by the personal income tax is denoted $\bar{f}$. In addition to the corporate income tax, corporate franchise tax, and property tax, we add another factor tax at the industrial level, termed the personal factor tax. The personal factor tax is collected by industry at rates τf_i. The personal income tax applied to capital income at the consumer level is given by

$$t_j=(\tau_j-\tau)k_j\bar{f} \qquad j=1,12 \tag{2}$$

where k_j is the capital income received by the jth consumer class. These consumer income taxes on capital income are both positive and negative and when aggregated over the twelve consumer classes yield no revenue. The modelled system operates exactly as a withholding system under which each industry pays tax on f_i of the capital used, at rate τ. The consumer income taxes in expression (2) correct the tax rate for each consumer class (those with rates above τ pay more taxes while those below get refunds). Since τ is chosen as the capital weighted average of marginal tax rates, the corrections sum to zero.

Each of the four integration plans implies a different set of values for f_i and for capital tax rates. Because of the government's balanced budget, however, it is important that it receives the same real tax revenue in the simulated equilibrium. Otherwise, the change in the pattern of government expenditures and transfers would affect the outcome and prevent the isolation of the effects of the

[6] *1976 Tax Expenditures*, U.S. Congress.

capital tax rate changes. Tax rates under each plan are therefore modified during computation until the resulting equilibrium tax yield allows government to make the same real purchases and give the same real transfers to consumer groups. The determination of real purchases and real transfers is based on Laspeyres price indices.[7] Different yield preserving taxes are considered. In dynamic analyses we consider equal yield tax replacements on a period by period basis.

The modifications used in our model to represent each plan are as follows:

Plan 1: Total Integration: Under this plan, the undesirable features of the corporate tax are removed by merging the corporate income tax and personal income tax. Corporate taxes are eliminated from the numerator of the new capital tax rate calculation. The personal income tax is changed to tax earnings rather than just dividends, implying a g_{RE} set to one. We calculate new f_i parameters using this new g_{RE}, but with the same capital income weights as before. These changes imply new personal factor taxes and thus new capital tax rates by industry.

Plan 2: Dividend Deduction from Corporate Tax Base: This plan's corporate income tax base is the undistributed profits of corporations. It is represented in model equivalent terms for each industry by removing a portion of the corporate tax paid from the 1973 capital taxation figures and recalculating the capital tax rate. The portion of corporate tax removed is given by the ratio of dividends to net of tax corporate profits by industry (*Survey of Current Business*, July 1976). The f_i and the personal income tax functions do not change.

Plan 3: Dividend Deduction from Personal Income Tax Base: This plan removes the taxation of dividends from the redistributive power of the income tax system. In model equivalent terms, it is specified by considering the effect of dividend deductibility on the income tax functions of households. The value of the g_D proportion of dividends taxable by the personal income tax is set to zero and all f_i are recalculated. Other adjustments are analogous to the description of Plan 1.

Plan 4: Dividend "Gross Up": This scheme gives stockholders an income tax credit of 15 percent of the corporate taxes paid by the firms in which they own an interest. It is most satisfactorily modelled as a reduction in the corporate taxes of each industry by the amount of the credit. This amount is then treated as additional dividends in the calculation of new f_i values. The new effective tax rates then include 85 percent of corporate income taxes and the new personal factor taxes. The higher dividends relative to retained earnings result in higher f_i and $\bar{f}$ values, so that consumers experience an increase in taxable capital income. The taxable nature of the credits are thus captured.

V. Results

Tables 3 and 4 present static efficiency and distributional results from the integration plans. Table 5 presents our calculation of dynamic effects. To obtain the static measures of efficiency changes displayed in Table 3, we first calculate changes in national income plus leisure, valued at prices before the policy change and after the policy change. We use these Paasche and Laspeyres quantity indices rather than compensating or equivalent variations because the utility contribution of savings may be inaccurately assessed by consumers due to their myopic expectations. Table 3 reports only the geometric mean of these two measures, for each tax replacement. The single period change in the real after-tax income of each of the twelve consumer classes is presented in Table 4.[8]

[7]Operation of the equal yield calculation is discussed in Shoven and Whalley.

[8]Because of the general equilibrium nature of these calculations, both sources and use effects are included in the Table 4 distributional results. Suppose, for example, that the rental price of capital rises in the simulated equilibrium. Low-income consumers tend to purchase outputs of lightly taxed, capital-intensive industries like housing, agriculture, and petroleum. Thus the uses side of income would have some regressive effects. On the sources side, note that the capital-labor ratio of income from our data is bowl shaped over income groups. This

TABLE 3—CHANGE IN REAL EXPANDED NATIONAL INCOME[a] UNDER VARIOUS ASSUMPTIONS
(in billions of 1973 dollars)

Tax Replacement Plan	Lump Sum Scaling[b]	Multiplicative Scaling[b]	Additive Scaling[b]
Plan 1: Full Integration with Indexing	11.135	6.206	6.369
Plan 1: Full Integration without Indexing	9.716	5.833	5.936
Plan 2: Dividend Deduction from Corporate Income Tax[c]	5.061	2.862	3.421
Plan 2: Dividend Deduction from Corporate Income Tax, with Extreme Behavior Assumption[c]	11.408	6.260	6.442
Plan 3: Dividend Deduction from Personal Income Tax[c]	3.840	2.544	2.600
Plan 3: Dividend Deduction from Personal Income Tax, with Extreme Behavior Assumption[c]	5.977	3.301	3.449
Plan 4: Dividend Gross-up	3.668	2.749	2.780
Equal Capital Tax Rates on Industry[d]		8.682	

[a]Real Expanded National Income incorporates the change in the valuation of leisure through induced variations in labor supply. The numbers reported are the geometric means of Paasche and Laspeyres index numbers, for each tax replacement, as described in the text.

[b]Lump sum scaling collects the extra government revenues necessary for equal yield from the twelve consumers in proportion to their original after-tax incomes. Multiplicative scaling collects the extra revenue by increasing the marginal tax rate of each of the twelve consumers by the same multiplicative factor. Additive scaling increases all marginal tax rates by the same absolute amount, as necessary to retain equal tax yield when the policy change alone would reduce revenues.

[c]The standard simulations for dividend deduction plans 2 and 3 assume that corporate financial policies do not change. In particular, the new f_i parameters are calculated with the old levels of dividends and retained earnings as weights for g_D and g_{RE}. However, these dividend deduction plans might encourage greater distribution of corporate profits. The "extreme behavior assumption" uses the sum of dividends and retained earnings as the weight on g_D, with no weight on g_{RE}.

[d]This result is for complete equalization of capital tax rates by industry. The property tax, corporate franchise tax, corporate income tax, and personal factor tax are included in this equalization. This result is presented for comparison purposes.

For the dynamic welfare effects shown in Table 5, we evaluate the instantaneous utility function H from equation (1). We report the sum of present value analogues of compensating variations using these utility functions, smoothing between equilibria to allow for growth rates within each of the separate periods we consider.[9] This measure reflects the amount (in 1973 dollars) which would have to be given to the twelve consumer groups to leave them indifferent between the present tax system and the tax integration plan.

We have calculated but do not report percentage changes in price and in output by industry, for each tax replacement. Other information on new capital and labor use by industry, taxes paid, and all types of demands are also available for each tax replacement.[10] The findings for each of the integration plans are as follows:

Plan 1: Total Integration: This plan removes only part of industrial discrimination in the taxation of capital income because property taxes remain as differential capital taxes by industry. Intertemporal distortion is

is largely due to their age structure. Since our model calculates a long-run equilibrium, where homogeneous capital is reallocated among industries, the new higher return to capital is earned by all capital owners regardless of their original portfolio. The higher price of capital would cause bowl-shaped gains on the sources side of income.

[9]Since the model calculates a sequence of six equilibria which are ten years apart, significant growth can occur during the intervening years. In any sequence, we calculate the annual growth rate implied by the difference between two successive equilibria, and we apply that growth rate to intervening years in the present value calculations.

[10]This additional information is available from the authors on request.

TABLE 4—PERCENTAGE CHANGES IN EXPANDED REAL INCOME[a] AFTER INCOME TAXES AND TRANSFERS BY INCOME CLASS, FOR EACH TAX REPLACEMENT

Consumer Group	Equal Capital Tax Rates on Industry[d]	Plan 1 Full Integration (Additive Scaling)[b]	Plan 1 Full Integration (Multiplicative Scaling)[b]	Plan 2[c] Dividend Deduction from Corporate Income Tax (Multiplicative Scaling)[b]	Plan 2[c] With Extreme Behavior (Multiplicative Scaling)[b]	Plan 3[c] Dividend Deduction from Personal Income Tax (Multiplicative Scaling)[b]	Plan 3[c] With Extreme Behavior (Multiplicative Scaling)[b]	Plan 4 Dividend Gross Up (Multiplicative Scaling)[b]
0–3,000	0.786	1.945	3.471	1.112	3.488	0.215	0.210	0.796
3–4,000	0.650	1.386	2.682	0.951	2.702	0.272	0.346	0.648
4–5,000	0.585	0.928	2.022	0.808	2.040	0.274	0.387	0.524
5–6,000	0.606	0.930	1.926	0.764	1.941	0.284	0.384	0.509
6–7,000	0.704	0.920	1.850	0.736	1.866	0.297	0.426	0.500
7–8,000	0.691	0.786	1.568	0.633	1.580	0.282	0.401	0.446
8–10,000	0.645	0.626	1.222	0.485	1.227	0.250	0.339	0.378
10–12,000	0.731	0.733	1.121	0.377	1.125	0.269	0.354	0.363
12–15,000	0.840	0.747	1.021	0.232	1.024	0.270	0.373	0.350
15–20,000	0.863	0.767	0.672	−0.014	0.670	0.274	0.350	0.283
20–25,000	1.063	1.022	0.654	−0.155	0.659	0.359	0.506	0.293
25,000+	2.240	3.202	1.388	−1.523	1.540	1.791	3.130	0.567

[a]Expanded real income includes leisure, valued at the household net-of-tax rate. Numbers shown are the arithmetic means of percentage changes to income based on Paasche and Laspeyres price indices.
[a,b,c]See fnn. b,c,d; Table 3.
[d]See fnn. b,c,d; Table 3.

substantially reduced. We consider equal yield tax replacements, as described earlier, such that taxes are scaled up to meet tax revenues from the corresponding period of the previous tax regime. We consider lump sum adjustments to income taxes, along with additive and multiplicative scaling of marginal income tax rates.

Interindustry discrimination is reduced enough to provide a $6 billion static welfare gain in each year (in 1973 dollars) for the cases with either multiplicative or additive scaling and inflation indexation of capital gains taxes. Without this price level correction, the efficiency gains are slightly less. Dynamic gains are sensitive to the replacement yield-preserving tax considered. With lump sum replacement, a gain of $551 billion occurs, and with multiplicative scaling a gain of $268 billion occurs. These figures are to be compared with a $49 trillion discounted present value of the future income stream for the *U.S* economy under the present tax system (after correction for population growth, in 1973 dollars). The sensitivity of these dynamic results to the replacement tax can be explained by the positive correlation between income and proportion of income saved. Since multiplicative scaling collects more tax revenue from high-income groups, it creates a greater distortion in their intertemporal choices.

Full corporate tax integration provides progressive gains to income brackets, shown in Table 4, with every class enjoying increased real income.[11] The importance of the structure of the replacement yield-preserving tax is apparent from Table 4. Multiplicative scaling helps lower-income groups substantially more.[12]

We do not need to consider changes in financial policies under this plan. With full integration, all forms of capital income are

[11]Although the simulated equilibrium is a Pareto improvement over the benchmark 1973 equilibrium, we have said nothing about the possible paths between the two. Short-run losses and transition costs should be considered before enacting such a change. Our model is essentially comparative static and does not measure these disequilibria or temporary influences.

[12]The U-shaped gains of the additive replacement can be explained by the higher return to capital in the simulated equilibrium. The capital-labor ratio of income is greatest for the low-income (retired) individuals and again for high-income individuals.

TABLE 5—DYNAMIC WELFARE EFFECTS: PRESENT VALUE OF COMPENSATING VARIATIONS OVER TIME[a] (In Billions of 1973 Dollars)[e]

Tax Replacement Plan	Lump-Sum Scaling[b]	Multiplicative Scaling[b]	Additive Scaling[b]
Plan 1: Full Integration with Indexing	551.376	267.760	335.608
	(1.126)	(0.547)	(0.685)
Plan 1: Full Integration without Indexing	473.786	252.990	305.394
	(0.967)	(0.517)	(0.624)
Plan 2: Dividend Deduction from Corporate Income Tax[c]	257.905	154.822	178.697
	(0.527)	(0.316)	(0.365)
Plan 2: Dividend Deduction from Corporate Income Tax, with Extreme Behavior Assumption[c]	566.016	269.449	340.575
	(1.156)	(0.550)	(0.695)
Plan 3: Dividend Deduction from Personal Income Tax[c]	229.815	151.656	166.003
	(0.469)	(0.310)	(0.339)
Plan 3: Dividend Deduction from Personal Income Tax, with Extreme Behavior Assumption[c]	379.228	220.252	256.670
	(0.774)	(0.450)	(0.524)
Plan 4: Dividend Gross-up	181.877	127.676	139.965
	(0.371)	(0.261)	(0.286)
Equal Capital Tax Rates on Industry[d]		454.546	
		(0.928)	

[a]To produce these measures, we first calculate a sequence of momentary equilibria through time. Endowments of capital are incremented through savings. Endowments of labor services are incremented through population growth and Harrod neutral technical change. We consider six equilibria which are ten years apart, in order to project annual consumption values over the 50 intervening years. For consumption beyond year 50, we have an appropriate treatment of the terminal conditions. The dynamic compensating variations are analogues of static concepts applied to the consumption sequence over time, assuming the first period discount factor is unchanged.

[b,c,d]See fnn. b, c, d; Table 3.

[e]The numbers in parentheses represent the gain as a percentage of the present discounted value of welfare (consumption plus leisure) in the base sequence. This value is $49 trillion for all comparisons, and only accounts for a population the size of that in 1973.

taxed identically. Since the tax does not depend on whether capital income is paid in interest, dividends, or retained, a change in either the debt-equity or dividend-retention ratio will not alter the new effective tax rates or the new f_i for the revised equilibrium calculation. The resulting solution would thus be the same even if the ratios changed.

Plan 2: Dividend Deduction from Corporate Income Tax Base: Here dividends are treated like interest for tax purposes, and we first assume that corporations continue to retain the same portion of income. The reduction of the corporate income tax base causes some levelling of capital tax rates and a resulting $3 billion increase in yearly national income. Dynamic gains under multiplicative scaling of tax rates are $155 billion. Under a lump sum replacement, dynamic gains are $258 billion. The reduced spread of dynamic results is due to the smaller revenue loss associated with Plan 2. When the amount of revenue to be replaced is small, the additive or multiplicative replacement schemes do not cause so much distortion of intertemporal choice. The static distributional impacts are disadvantageous to the higher-income groups, reflecting the fact that less income is taxed at the flat corporate rate and more at the progressive personal rates.

Under our "standard" treatment of Plan 2, the dividend-retention ratio is assumed constant even though there does exist an incentive to replace retained earnings with now nontaxed dividends. For this reason, we also consider the extreme case where all corporate earnings are distributed. The corporate income tax would thus be effectively eliminated, and f_i calculations would proceed on the assumption that all corporate earnings get multiplied by the higher .96 for g_D. The static gain for such a tax replacement is

around $6 billion per year, the same as under Plan 1; the dynamic gains are also comparable. These welfare gains are substantially above the fixed-behavior estimate because corporate decision makers have, in effect, reduced the distortion of the corporate income tax with its differing effective capital tax rates. The static distributional results of the Plan 2 extreme-behavior case show more progressive gains among consumers.

Plan 3: Dividend Deduction from Personal Income Tax Base: The reduced tax on dividends again implies lower tax rates on heavily incorporated industries and a levelling of all rates in general. This occurs through the lower f_i for dividend paying industries. Static welfare gains are about $2.5 billion per year; dynamic gains under multiplicative scaling are about the same as Plan 2, at $152 billion, but under lump sum replacement are lower than Plan 2, at $230 billion. The multiplicative results reflect the importance of the deduction from the upwardly scaled income tax. As might be expected, Table 4 shows that Plan 3 has more regressive effects than the second plan, since dividend income is all taxed at the corporate rates instead of being taxed at progressive personal tax rates.

Under extreme financial policy behavior, where firms no longer retain earnings, both the static and dynamic gains are somewhat larger. The corporate tax remains the same, but new f_i include all corporate earnings as dividends with a g_D of zero. Less corporate income is subject to the personal income tax. The difference between results with and without the extreme-behavior assumption is less than for Plan 2 because the personal income tax deduction does less to eliminate interindustry discrimination than does the corporate income tax deduction of dividends. Equity effects are regressive for the extreme-behavior case of Plan 3, as with the case in which we assume no change in financial policies.

Plan 4: Dividend "Gross Up": All plans that decrease the corporate income tax only on dividends can be termed partial integration plans. The fourth plan, because it reduces only part of the tax on dividends, might be called a partial-partial plan. The tax system is changed to a lesser degree, and the static welfare gain is small, at $2.8 billion per year. Dynamic gains under multiplicative scaling are $128 billion, under additive scaling are $140 billion, and under a lump sum replacement are $182 billion.[13] Equity effects are closer to proportional than under Plan 1.

We also report, as a basis for comparison, the effects of complete equalization of capital tax rates by industry under an equal government revenue constraint. We report these results even though we realize that complete equalization of capital tax rates is not a realistic policy proposal. In this case, we eliminate tax discrimination on capital use among industries, use a single tax rate for all industries, and tax equally all capital income at the personal income tax level. Capital tax rates are set to a common rate, providing government with enough revenue to maintain its real purchases. The f_i parameters are all reset to f, the overall fraction of capital income which is effectively fully taxed by the personal income tax system. The resulting efficiency gains are larger than those of the four integration plans and represent the maximum possible increase in expanded national income from the elimination of interindustry capital tax distortions.[14]

Results in Table 3 indicate that the efficiency gains from equalizing capital taxes by industry is about $8.7 billion per year in 1973 dollars. Table 4 shows that the gain turns out to be distributed in such a way that every group experiences an increase in real income, and thus a Pareto improvement oc-

[13]Here, again, the spread between the dynamic welfare gains is less than that of full integration because this plan involves smaller revenue loss than full integration. Multiplicative scaling makes up most revenue from high-income, high-saving consumers, and it thus reduces future capital stocks and incomes. The dynamic lump sum and additive cases show that the dividend gross-up does substantially less to improve interindustry resource allocation than other plans.

[14]The capital tax equalization removes all interindustry distortions, but it leaves intertemporal distortions because the common capital tax rate is scaled to preserve total tax revenue. The full integration with lump sum replacement, described above, has larger efficiency gains in both Tables 3 and 5 because it removes some interindustry distortions and some intertemporal distortions.

curs. Dynamic gains in this case (Table 5) are $455 billion, which is about 0.9 percent of the discounted present value of the future *U.S.* income stream after correction for population growth.

Perhaps the most interesting of our results for the integration plans are the dynamic results which suggest significant potential gains from corporate tax integration, provided replacement taxes do not excessively interfere with intertemporal consumption choice. There appears to be a tradeoff between achieving progressive or proportional income gains through multiplicative scaling and maximizing the dynamic efficiency gain: the largest intertemporal gain could be secured by taxing the poor who do not save.

VI. Conclusion

In this paper we have analyzed four alternative plans for corporate and personal income tax integration in the United States, by using a recently constructed medium-scale general equilibrium model of the *U.S.* economy and tax system. The paper includes a brief discussion of the model and its use of data, in addition to outlining characteristics of the integration plans and their representation in model equivalent form.

Total integration of personal and corporate income taxes is shown to yield static efficiency gains of $6 billion per year using 1973 data, and the present value dynamic gains range from $253 billion to $551 billion in 1973 prices, depending on the yield preserving tax. Dividend deductibility from either the corporate income tax or the personal income tax results in a static efficiency increase of slightly less than half of the gains from full integration. A 15 percent dividend gross-up scheme yields somewhat less than dividend deduction from the corporate tax but a little more than deduction from the personal income tax. The distributional impacts vary among plans; full integration with multiplicative scaling of marginal income tax rates to preserve tax yields is shown to imply a progressive change in the distribution of real income even though every class is better off. Dividend deductibility from the personal income tax is shown to have a beneficial impact slightly more advantageous to high-income groups, while dividend deductibility from the corporate income tax redistributes from high to low income groups. The dividend gross-up plan is roughly proportional. In the sensitivity of dynamic gains to the yield preserving tax we find an interesting result. It suggests that the potential gains under integration from removal of intertemporal distortions would be significantly reduced if marginal income tax rates are raised, particularly if the higher-income groups, who are also larger savers, face larger tax rate increases.

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Income Maintenance Schemes under Wage-Rate Uncertainty

By FRANK A. COWELL*

Economists' thinking on taxation schemes and work incentives is usually founded on a set of propositions concerning the supply of labor under perfect certainty.[1] Insofar as labor is supplied under a regular fixed-wage contract with no risk of involuntary unemployment, this neglect of uncertainty seems reasonable. However, if one applies tax theory to income maintenance schemes for the poor, the assumption of perfect certainty could be misleading. Accordingly, we need to know whether risk on the seller's side in the labor contract significantly alters the market response to tax and subsidy schemes. If it does, then how does this affect a government's choice of design of an income maintenance scheme?

In this article, I shall concentrate specifically on wage-rate uncertainty. As a preliminary, it is interesting to note the number of ways in which such uncertainty affects poor people's incomes: 1) those who are self-employed receive a random return to the weekly hours they devote to their job; 2) "piecework" or other productivity-related employment contracts clearly have an uncertainty component; 3) promotion and bonus schemes can have a similar effect in the life cycle of poverty. Many currently low-paid workers know that the prospect of a higher wage through career-ladder advancement may be obtained by currently working more hours or at a greater intensity. At the time that the labor supply decision is made, of course, the returns to this marginal effort are uncertain. 4) The possibility of unemployment can also be interpreted in the context of a random wage—though more care is needed here. If the hours-of-work decision is made collectively (for example, via union representation), although the going wage-rate may be known with certainty, for *each individual* it may be uncertain whether he will be able to find employment or not, or indeed keep his job at the going rate.

Why does wage-rate uncertainty raise special problems? There are in fact a number of issues involved[2] but let me anticipate the formal argument of Section I to IV by some reasoning on basic neoclassical theory. I do so in two steps.

First, take the standard case of an individual with a determinate wage, where utility is a function of consumption and leisure. Increase the marginal tax rate (*MTR*) and his/her nonlabor income. If this is done so as to ensure exact compensation in utility terms, then obviously we isolate a conventional, pure substitution effect and labor supply is reduced. If the compensation is such that *ex post consumption* remains constant, then, again, labor supply is reduced as long as consumption is a superior good. If the compensation is such that *ex post net tax liability* remains constant, labor supply is reduced as long as leisure is a superior good.

Second, take the standard pure portfolio problem. An individual is deciding how to allocate a fixed total wealth between a safe asset bearing a given rate of return, and an asset with a higher, but risky, rate of return. I assume that utility depends on disposable income, that the individual aims to maximize

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[1]Examples of the theory of taxation and labor supply under certainty are M. G. Allingham and Henry Cassidy. One paper that has dealt with the general problem of wage rate uncertainty is by M. J. Block and J. M. Heineke.

[2]For a more general treatment, see my forthcoming article.

expected utility, that he is risk averse, but that his absolute risk aversion decreases with his overall wealth. Now I introduce an income tax with full loss offset. Then the standard theory predicts that the proportion invested in the risky asset (a) will increase if *either* the return on the safe asset is zero and the *MTR* rises, *or* government lump sum transfer income increases, *or* (except in a few pathological cases) if tax progressivity increases. Moreover, even if the safe asset return is not zero, then the *substitution effect* on a is positive.[3] The reason for this is that, in each case, either the government effectively reduces the dispersion of possible returns on the risky asset, or it increases the guaranteed real income of the investor, or it does both.

Herein lies the problem for the analysis of income maintenance policies for poor persons with risky wage contracts. If the policy is made more progressive so that the *MTR* and income guarantee go up, then, on the one hand, deterministic labor supply theory tells us that there is a negative substitution effect so that labor supply would be reduced. On the other hand, if we consider the person allocating a "portfolio" of a given number of hours between safe leisure and risky work, then portfolio theory tells us that there is a positive substitution effect so that increased progression would increase the proportion of time devoted to risky pursuits.

Obviously the two approaches must be reconcilable within an appropriately specified neoclassical model of choice under uncertainty. In the next section I shall construct such a model. In Sections II and III, I shall examine the interaction of conventional income and substitution effects, and of variance-reduction effects: does increased progression still reduce work incentives? What is the effect of social insurance payments on work effort? Finally in Section IV, I consider whether it is still true that wage subsidy schemes are more "efficient" than negative income taxes in terms of implicit labor supply disincentives.[4]

I. The Model

Since my informal discussion suggested that there were two offsetting effects of tax-rate progression when the wage rate is stochastic, it might be guessed that the outcome depends crucially on the stochastic specification. This guess is confirmed by the general results proved formally in the Appendix. It is, however, rather difficult to get much insight from a very general exposition, so I shall employ an extremely simple version of the model; it will readily be seen that the qualitative results will carry over to more complex and realistic specifications. Hence, let the combined tax and income maintenance systems be represented by a tax function:

$$T = my - B \tag{1}$$

where m is the uniform *MTR*, B is a transfer which may or may not be exogenously determined, T may be positive or negative, and y is original income which is given by

$$y = Wh \tag{2}$$

Here $h \in [0, 1]$ is the proportion of total time available that is actually spent at work, and W is the stochastic wage rate. The simplification I shall introduce for the distribution of W is to take this as a simple two-state variable:

$$W = \begin{cases} w \text{ with probability } 1-p \\ w' \text{ with probability } p \end{cases} \tag{3}$$

with $w' < w$, so that we may think of w and w' as, respectively, success and failure in the risky labor contract. All the results of this paper can be obtained using (3), but I shall simplify further by putting $w' = 0$. The advantages of doing this are that it saves a

[3] In fact, the positivity of the substitution effect holds even if the safe asset is nontaxable, as long as relative risk aversion is increasing. For the standard portfolio model, see Jan Mossin (1968), Joseph Stiglitz, S. M. Ahsan, and my 1975 article.

[4] On this subject see Irwin Garfinkel, Jonathon Kesselman (1969, 1976), Robert Schlenker, Richard Zeckhauser, and Michael Barth and David Greenberg.

good deal of algebra, and has a natural interpretation in terms of the fourth kind of uncertainty I shall consider.[5]

Disposable income c is obviously $y-T$, so that we have the stochastic budget constraint:

$$(4)\qquad \begin{cases} c^1 = B + vhw & (\text{"success"}) \\ c^0 = B & (\text{"failure"}) \end{cases}$$

where $v=1-m$. Let us turn now to consumer preferences. Once again we expect the particular shape of the utility function to be crucial in determining the outcome of the two opposing forces cited in the introduction, and once again I shall simplify in order to be able to interpret the parameters easily. Let us take a form which has been shown to give a variety of plausible shapes for the labor supply function:[6]

$$(5)\qquad U = -\frac{1}{\beta\varepsilon}\left[(c-k)(l-h)^{\beta}\right]^{-\varepsilon}$$

where the parameters l, k, β, ε satisfy $0<l\leqslant 1, \beta>0, \varepsilon>-1$. If k is positive it may be interpreted as "subsistence minimum" consumption. The quantity $l-h$ represents the amount of leisure enjoyed. This utility function yields strictly declining absolute risk aversion, and increasing/constant/decreasing relative risk aversion depending on the sign of k; thus although simple in form, it gives us a large variety of interesting cases.

As a final piece of preliminary work we need to discuss the distinction between uncertainty of types 1 to 3 and uncertainty of type 4 mentioned in the introduction. Under types 1–3, the person obviously makes a decision to work h hours, and has to accept whatever W is realized: leisure is measured by $l-h$ whatever the realized value of W. What happens with type 4 uncertainty? Here we imagine workers *collectively* offers a contract of h units labor for a given wage w. However, for each man it is uncertain whether he will be able to secure a job at that wage (if unemployed) or keep his job (if employed) and thus secure the wage w for his effort. Then p becomes the probability of being unemployed.[7] There remains a difficulty concerning the amount of leisure realized. Two extreme assumptions are possible. (a) The disutility of being involuntarily unemployed exactly matches the disutility of work if employed—in which case leisure is effectively given by $l-h$ as before. This is the position taken by David Sjoquist, and can be justified by noting that if unemployed search costs in the form of time and goods will usually be incurred by those wishing to work, and that higher search costs are presumably incurred by those willing to work more. (b) The disutility of involuntary unemployment is nil. In this case:

$$(6)\qquad \textit{leisure} = \begin{cases} l-h \text{ with probability } 1-p \\ l \text{ with probability } p \end{cases}$$

This is the position taken by Hartley and

[5]If w' is nonzero, the essential difference in what follows is that the ratio w'/w further modifies the conditions under which "perverse" results are obtained.

[6]See Yoram Barzel and Richard McDonald. Consider the no-tax case under perfect certainty and let there be unearned income I. Then it is easily seen that

$$\frac{w}{h}\frac{\partial h}{\partial w} = \frac{\beta[I-k]}{wl\beta[I-k]}; \quad \frac{I}{h}\frac{\partial h}{\partial I} = \frac{-\beta I}{wl\beta[I-k]}$$

each of which may be either positive or negative if $k\neq 0$. We could also consider $0>\beta>1$, but this makes (5) slightly more complicated.

[7]Taking p as parametrically given is a strong assumption, since it implies that it is unaffected by the optimal amount of labor supplied or of effort in job search, and is thus unaffected by the tax system. It is, however, a device used elsewhere in the literature (see, for example, Michael Hartley and Nagesh Revankar) and to relax it satisfactorily would probably involve a thorough-going model of temporal risk, a complication which I have been anxious to avoid. A second difficulty concerning p may be dealt with more easily. It is evidently reasonable to suppose that this probability be different for an employed man from that for an unemployed man. This presents no problem for the formal analysis as long as the person has a clear idea of what the probability of employment (success) is at the time he makes the labor supply decision. It is true that this probability may differ from that facing his neighbor, but that will not alter the qualitative results of the paper since it deals only with *individual* behavior and subjective probabilities (of any magnitude). However, this difficulty would become significant if an attempt is made to aggregate over individuals, and to interpret p as an observable rather than a subjective probability.

Revankar, and by Gideon Yaniv. It has the rather unattractive implication that time when one is laid off is pure leisure, thus destroying the distinction between voluntary and involuntary unemployment. The truth probably lies between the two extremes, so that while I shall work principally with case (a) which corresponds to uncertainty of types 1–3, I shall also state results for case (b).

In case (a), maximizing EU subject to (4) we get an interior solution h^* given by

$$(7)\quad z(h^*)=-\beta\frac{[1+x]^{-\varepsilon}+qx^{-\varepsilon}}{[1+\alpha][1+x]^{-\varepsilon}+q\alpha x^{-\varepsilon-1}}$$

where for convenience I have defined the following new variables $z(h^*)\equiv[h^*-l]/h^*$, $x\equiv[B-k]/vwh^*$, $q\equiv p/1-p$, $\alpha\equiv(1/vw)\partial B/\partial h$. Note z is an increasing function of h^*, that x has the interpretation of "excess transfer income" as a proportion of net earnings, and that x will depend on the type of tax or maintenance program being considered.

In case (b) the corresponding relation is

$$(8)\quad z(h^*)=-\beta\frac{[1+x]^{-\varepsilon}}{[1+\alpha][1+x]^{-\varepsilon-1}+\alpha qx^{-\varepsilon-1}\left[1-\frac{1}{z}\right]^{\beta\varepsilon}}$$

These two rather opaque formulae, (7) and (8), yield fairly simple results for the various particular schemes we shall now examine.[8]

II. Income Taxation

The simplest case of a tax scheme which incorporates negative income taxation is found by requiring B to be a constant in all states of nature, so that the transfer depends neither on the decisions of the worker, nor on whether success or failure occurs. This implies that α is zero, and then, in case (b), it is clear that should unemployment arise the person would enjoy maximum leisure combined with a lump sum guarantee, *whatever work contract he makes*. Hence the probability of unemployment would have no effect on the labor contract in this extreme case. This can be checked by putting $\alpha=0$ in (8) and noting that q disappears. However if w', the reward for failure in equation (3), is nonzero or if the world operates like case (a) (or some intermediate case between (a) and (b)) this independence result will *not* hold. Hence, we need to see what happens with case (a). Putting $\alpha=0$ in (7) yields

$$(9)\quad z=-\beta[1+x]\left[1+q\left[1+\frac{1}{x}\right]^{\varepsilon}\right]$$

Observe also that

$$(10)\quad \frac{\partial z}{\partial x}=z_x=-\beta-\beta q\left[1+\frac{1}{x}\right]^{\varepsilon}\left[1-\frac{\varepsilon}{x}\right]$$

Note first an implication of (9) using the definition of the variables x and z. Simple rearrangement of (9) reveals that q is a decreasing function of h^* and vice versa.[9] So increased risk of the employment contract (interpreted as a higher probability of failure) reduces labor supply. Now consider (10). Notice that this is in the form of [constant]+[expression involving q]. As $q\to 0$ (perfect certainty), obviously only the constant remains on the right-hand side of (10). We may thus think of the first term of the right-hand side as a "certainty component" and of the second term as an "uncertainty component" in the analysis of a small change in x. While the former is of unambiguous sign, the latter *is* ambiguous. The uncertainty component only has the same sign as the certainty component if x, the ratio of excess transfer income to net earnings, exceeds ε. Now consider what may happen to the sign of z_x. Suppose that at $q=0$, $\varepsilon>x$. Then allow q to increase: for a certain interval $(0, q)$ the uncertainty component may dominate, so that

[8]One further note of caution: for some maintenance schemes the value of B, and hence α, will depend on the particular state (that is realized; for example, whether the person is unemployed). This additional complication which we will consider later has not been written into (7) and (8).

[9]This result is similar to that obtained by Sjoquist and is true for *any* concave utility function U.

$z_x<0$. Thereafter, for a certain interval, $(q, \bar{q})$, the uncertainty component dominates, so that $z_x>0$. However, as q is increasing, h^* is falling, and x is rising. Assuming there is a finite $\bar{\bar{q}}$ such that $h^*\to 0$ as $q\to\bar{\bar{q}}$, then x is bound to exceed ε eventually, and so for $q>\bar{q}$ we have $z_x<0$ once again. Thus for a high probability of failure the qualitative effect of an increase in the x-ratio on h^* is the same for low values of q, while for intermediate values the effect may be reversed (see Figures 1 and 2 below).

Let us see what this implies for changes in tax parameters. First, differentiate z to obtain

$$(11)\qquad (l/h^{*2})dh^*=z_x dx$$

If B is kept constant and m is increased, then $dx=x[(1/v)dm-(1/h^*)dh^*]$. On substituting this in (11) and rearranging we have

$$(12)\qquad \frac{\partial h^*}{\partial m}=\frac{h^*}{v}\left[1+\frac{l}{h^*xz_x}\right]^{-1}$$

This is negative if $-l/xh^*<z_x<0$, and is positive elsewhere.[10] Hence (12) may have either sign for different values of q, which is in sharp contrast to the certainty case for this model. For if we substitute for x and let $q\to 0$ we find the limiting value of (12) is $[h^*-l/(1+\beta)]/v$ which is strictly negative.[11] Second, if m is kept constant and B increased, reevaluation of dx in (11) yields

$$(13)\qquad \frac{\partial h^*}{\partial B}=\frac{h^*}{B-k}\left[1+\frac{l}{h^*xz_x}\right]^{-1}$$

Evidently the same conditions on the sign prevail as in the case of (12), provided that $B>k$; and in the case of certainty expression (13) becomes $-\beta/[vw(1+\beta)]$ which is again always negative. Thus, even though the labor supply curve under certainty is of a conventional, upward-sloping type, for certain values of the probability of unemployment and of the elasticity of utility with respect to consumption (such that $z_x\notin(-l/xh^*,0)$) we have the unconventional result that *labor supply increases with an increase in the MTR or the lump sum transfer.*

However, single parameter changes are of only limited interest. We should also like to know what happens if both tax parameters are manipulated so that the system is made more progressive. Following my 1975 article, there appear to be two interesting and practical ways to define an increase in progression: a positive dm accompanied by a dB such that $Edt=0$ (*so expected tax liability or expected net benefit* entitlement remains unaltered). Evaluating dx in each case,[12] using manipulations similar to those above, we get in each of these two cases:

$$(14)\qquad \left.\frac{dh^*}{dm}\right|_{Edc=0}=\frac{h^*}{v}\left[1+\frac{l}{z_xh^*[x+1-p]}\right]^{-1}$$

$$(15)\qquad \left.\frac{dh^*}{dm}\right|_{Edt=0}=\frac{h^*}{v}\left[1+\frac{1}{x+1-p}\times\left[\frac{l}{z_xh^*}-\frac{1-p}{v}\right]\right]^{-1}$$

Note that under certainty expression (14) and (15) became, respectively, $[h^*-l]/v$ and $[h^*-l]/[v+\beta]$ each of which is always negative, as we would expect. However, if the uncertainty component "outweighs" the certainty component in (10), so that $z_x>0$, we find the remarkable result that (14) is negative. This is also true in (15) if $vl/h^*[1-p]>z_x>0$. So even though leisure and consumption are superior goods there are values of the probability of failure, and of the risk aversion parameter such that we get the per-

[10]Recalling that β and $1+\varepsilon$ are necessarily positive, examination of (9) and (10) reveals that the lower constraint cannot be violated for any q.

[11]The first-order condition guarantees that $1-l/h^*<-\beta$.

[12]$E\,dc=0$ implies $-wh\,dm+vw\,dh+[1+q]dB=0$. Now we have as an identity:

$$dx/x=dB/B-k+dm/v-dh/h$$

Substituting for dB from the first relation in the second and noting that $1/[1+q]=1-p$ yields the result. A similar manipulation produces the condition for $E\,dT=0$.

verse effect of increased progression *increasing* labor supply!

More formally we can state: *For certain values of q and ε the effect of an increase in the MTR combined with a change in the transfer such that expected tax payments/receipts are kept constant is to increase work incentives. Whenever this occurs for the expected tax-compensated case, it also occurs for the expected consumption-compensated case and the uncompensated cases.*[13]

So far I have only demonstrated the possibility of wage uncertainty yielding perverse results on progression and work incentives. Let us then consider more closely under what conditions this unusual result will occur. Clearly the three quantities which together determine whether the "certainty" or "uncertainty" effect dominates are ε (risk aversion minus 1), p, and x (the ratio of excess transfer income to earned income). For the purposes of illustrating how these three interact it is more convenient to use $\zeta = xh^* = B - k/vw$. Clearly we will be interested in critical values of (ε, p, ζ) such that z_x is exactly zero. These values form the boundary points of a convex set, within which cases of perverse labor supply response are to be found, and outside which one finds cases of conventional labor supply. The contours of this set are illustrated in Figures 1 and 2 for the special case $l = \beta = 1$. Notice that the upper part of each contour is labelled $\bar{p}$, and the lower part $\underline{p}$. The reason for this is that at any given value of ε and ζ, as we increase p from zero the first time the boundary is crossed at $\underline{p}$ indicates the point at which we switch from conventional to unconventional supply response; the second crossing at $\bar{p}$ indicates the point at which we revert to conventional behavior. Thus, for example, given $\zeta = 0.1$ (excess transfer income is 10 percent of the net wage rate), and $\varepsilon = 1$, if the probability of "failure" (unemployment) lies between about 7 and 52 percent, we find the perverse case

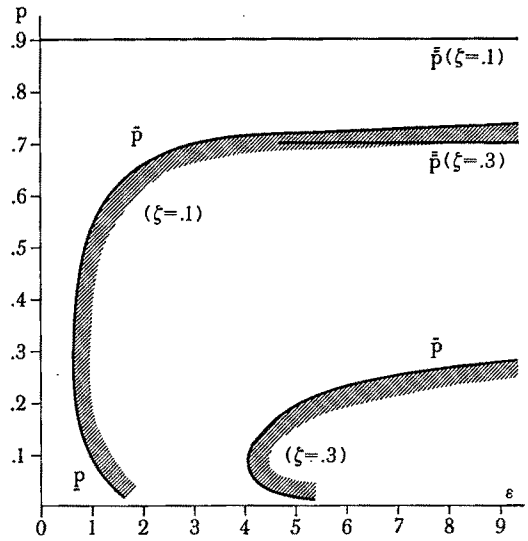

FIGURE 1. CRITICAL VALUES OF $\bar{p}$ AND ε

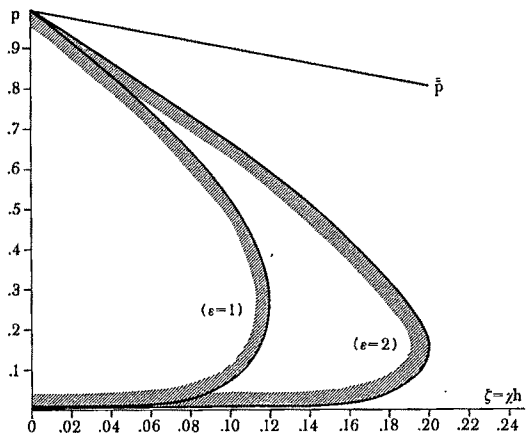

FIGURE 2. CRITICAL VALUES OF ε AND xh

of labor supply increasing with an increase in tax progression. From either picture it is readily seen that the *higher* the elasticity of utility with respect to consumption, and/or the *lower* the ratio of transfer income to net earnings, the larger is the interval $(\underline{p}, \bar{p})$ in which the perverse result arises.

Also in Figures 1 and 2 is plotted the set of values (ζ, ε, p) such that $h^* = 0$; this is marked as $\bar{p}$. Notice that as the ratio ζ is increased, two possibly undesirable effects occur. (i) As we have just seen, the range within which it is possible to get both in-

[13]The justification of this last remark is simple. The "perverse result" is obtained in the uncompensated cases, etc., if z_x is positive; the result is obtained in the expected-tax-compensated case if z_x lies within a given subset of the positive halfline. This result generalizes to *any* concave utility function for which leisure and consumption are superior.

creased progression and greater work incentives at the margin shrinks. (ii) The probability level at which no work whatsoever is offered also falls. This is given by $\bar{p}=1-\beta\zeta/l$ so that in our case, if $B-k=vw$, then $h^*=0$, whatever the labor market conditions. One obvious implication of this is that as we look at different sections of the labor market, given that the tax/transfer scheme is common to all, the higher is the wage rate, the lower is the "cutoff" probability $\bar{p}$ at which the individual will not seek work at all.

Hence, for poor people who face wage uncertainty of types 1 to 3 (or type 4) when assumption (a) holds), we have a surprising result for the negative income tax: increased progression can accompany increased work incentive even when the person is exactly compensated. The segment of the population that is potentially in such a position is quite large. Even if we ignore the problem of unemployment (and hence that of whether assumption (a) or (b) is relevant) we find that about 22 percent of poor American families are headed by partially or wholly self-employed persons, while about 18 percent of all poor families are headed by wholly self-employed persons.[14] What this means is that for risk-averse families with low unemployment income we can manipulate the tax/income maintenance scheme to secure a more equitable distribution of disposable income without incurring a reduction in social product through the labor supply response. This is independent of the labor supply response of the nonpoor and relies solely on the variance-reducing effect of the policy instruments.

III. Wage Taxation and Social Insurance

By contrast to Section II, I now wish to use the *wage rate* as the base for a taxation and income maintenance program to see if similar conclusions apply. The obvious way to do this is to write $B=Dh$ in (1), with D a constant.[15] Using (2) this then yields a wage tax/subsidy scheme with marginal tax rate m and a break-even point at $w=D$.

However, if the analysis is to continue to cover the possibility of unemployment (as the fourth source of uncertainty), the wage subsidy must be complemented by some social insurance scheme when the person has no job. Contrast this with the NIT which could be discussed in isolation since a minimum level of consumption was guaranteed in *all* states of the world by the NIT alone. The way the unemployment insurance is administered will crucially affect the labor supply decision.

Consider first of all a system which ties the unemployment compensation to the normal contracted hours. Disposable income is then

$$(16)\quad \begin{cases} c^1=Dh^*+vh^*w, & \text{if employed} \\ c^0=Dh^*, & \text{if unemployed} \end{cases}$$

As before, we may distinguish case (a) where leisure is always given by $l-h$ (applicable to uncertainty types 1 to 3 and capturing one polar case of type 4 uncertainty, unemployment) and case (b) where leisure is determined according to equation (6) (the other extreme assumption about unemployment).

In addition to these two cases, however, we must consider an alternative way of running the insurance system.[16] Suppose benefits are *not* related to regular earnings, or work hours, but are a given sum $\bar{B}$, then we have

$$(17)\quad \begin{cases} c^1=Dh^*+vh^*w, & \text{if employed} \\ c^0=\bar{B}, & \text{if unemployed} \end{cases}$$

where I assume $\bar{B}<c^1$ in order to avoid the problem of sybaritic excesses on Social Security. Once again I could distinguish the two rival assumptions about leisure under type 4 uncertainty. However budget constraint (17) together with the assumption of equation (6) turns out to yield the same result as our case (a) and therefore does not

[14]Source: data tapes for *CPS* Series P60 for the year 1975. I am grateful to Nancy Williamson for providing these figures.

[15]It will be seen to be a simple version of that discussed by Zeckhauser, Garfinkel, and Schlenker, for example.

[16]A budget constraint similar to (17) is used by Hartley and Revankar, and by Sjoquist. Yaniv uses a constraint similar to (16).

need separate analysis. The three cases for consideration underwage subsidy are therefore. (a) budget constraint (16) and leisure $=l-h$; (b) budget constraint (16) and leisure given by (6); (c) budget constraint (17) and leisure $=l-h$.

The expression that one derives for the optimal solution by substituting from (16) or (17) into (7) or (8), respectively, turn out to be quite complicated except in case (a). Hence I shall make the simplifying assumptions that $k=0$ (so that $x=D/vw$) and that $B=\bar{B}=Dh^*$. The more general version is unlikely to provide substantially more insight, and unconventional results are far more easily discussed using this simple and conventional model. Optimal labor supply in the three cases is then given, respectively, by

$$z=-\beta \tag{18a}$$

$$z=-\beta\left[1+qx^{-\varepsilon}[1-1/z]^{\beta\varepsilon}\right]^{-1} \tag{18b}$$

$$z=-\beta\left[1+q[1+1/x]^{\varepsilon}\right] \tag{18c}$$

with the corresponding formulae for z_x being

$$z_x=0 \tag{19a}$$

$$z_x=\frac{z^2}{x\beta}\left[s-\frac{x^{\varepsilon}}{q\varepsilon}s^{\beta\varepsilon}\right]^{-1} \tag{19b}$$

$$z_x=\beta q\varepsilon[1+1/x]^{\varepsilon-1}/x^2 \tag{19c}$$

where $s\equiv z/z-1$.

We want to see what effect uncertainty has on labor incentives. Note that in this simple model with Cobb-Douglas utility, the certainty case is given by (18a), (19a)—setting $q=0$ elsewhere confirms this well-known result. In general, under perfect certainty, whether a parameter change increases or decreases work incentives depends imply on (i) whether the net wage is increased, (ii) whether the regular labor supply function is forward- or backward-bending. With uncertainty we find the picture rather more complex since the parameter change will alter the effective dispersion of rewards. In case (c), we may use the definitions of x and z to deduce immediately that $h_m^*, h_D^*\gtrless 0$ as $\varepsilon\gtrless 0$. Hence, in this case, if the probability of unemployment is positive, an increment in either the *MTR* or the guaranteed wage increases/decreases labor supply according as the elasticity of utility with respect to consumption is positive or negative. In other words, quite risk averse people ($\varepsilon>0$) will increase their labor supply when the wage tax/subsidy scheme is made more progressive (D and m go up). Less risk-averse people (for whom $-1<\varepsilon<0$) decrease their labor supply. Manipulation of (19b) is obviously a little harder, although if $\varepsilon<0$, we evidently have $z_x>0$ and hence $h_m^*, h_D^*>0$. If ε is sufficiently large and positive, then we may find $z_x, h_m^*, h_D^*<0$.[17] Hence in this case increased progression of the wage tax/subsidy makes high-risk-averse people work less and low-risk-averse people work more.

Cases (b) and (c) because of their different treatment of leisure combined with their different treatment of the unemployment guarantee evidently produce "mirror-image" results. In each case, increased risk (a higher q) increases the magnitude of the incentive effect.

The appropriate answer will depend on the institutional set-up, the nature of the uncertainty, and on preferences. The institutional setup determines whether (16) or (17) is the relevant constraint. The nature of the uncertainty and workers' preferences will determine which treatment of leisure is appropriate. Personal preferences, in turn, fix the degree of risk aversion. In any case, it is clear that as with the income tax the policy instruments may be maneuvered to yield higher income support for the poor without *necessarily* producing a concomitant reduction in labor supply and social product.

IV. Comparison of the Schemes

So far I have shown that wage-rate uncertainty drastically alters the relationship between progressivity and labor supply in a certain section of the population for each of two income maintenance programs.

[17]This can be established by noting that for positive, finite ε, the sign of z_x depends on the magnitude of $x^{\varepsilon}/q\varepsilon$—if this ratio is sufficiently large then $z_x<0$. Since x and q may have any positive value we can see that z_x may indeed be negative for $0<\varepsilon<\infty$.

To compare the performance of the two programs correctly requires a thorough consideration of the welfare economics of this simple two-good economy. However, let us examine one straightforward issue which has been prominent in the literature—which scheme provides greater work incentives? Clearly, the answer depends on the type of model we use and the basis for comparison of the schemes. I deal first with uncertainty of types 1–3, and type 4 with the assumption that leisure$=l-h$; and shall consider three bases for comparison, as follows.

A. *Universal Equivalence*

Here it is assumed in each state of nature *either* that the schemes each produce the same level of disposable income, *or* that they each produce the same tax revenue/subsidy requirement, *or* that they each produce the same utility level. Notice that, since the probabilistic structure is very simple, it is possible to guarantee such universal equivalence with only the small number of tax parameters available. Call optimal labor supply under *NIT*, under wage-subsidy scheme (a), and under wage-subsidy scheme (c), h^*, h^{**}, h^{***}, respectively.

Since it is clear from (9), (18a), and (18c) that $h^{**}>h^{***}$ whatever the x-ratios of the three schemes, we do not need to include wage-subsidy scheme (a) in the comparisons, since this will dominate the other two schemes. We may restrict ourselves to a comparison of h^* and h^{***}.

Consider first universal equivalence on a disposable income (consumption) basis. Requiring that c^0 be uniform under all three schemes evidently means $B=\bar{B}$. If we also require that c^1 be uniform under each scheme:

$$(20) \qquad vwh^*+B=\hat{v}wh^{***}+Dh^{***}$$

where $\hat{v}$ is the value of v under wage-subsidy scheme (c). Assuming for convenience that under scheme (c) $\bar{B}=Dh^{***}$, as in the previous section, then dividing (20) by c^0, immediately reveals that we have identical x-ratios (given $k=0$), and using equations (9) and (18c) we have the result that for this simplified utility function $z(h^{***})>z(h^*)$ so that $h^{***}>h^*$. A similar argument establishes an identical result for equivalence on a utility basis.

Next consider the case of identical tax receipts/subsidy payments under each scheme. Obviously we must again have $B=\bar{B}$, and we shall assume again that for the (c) program $\bar{B}=Dh^{***}$. Then if tax revenues are also equal,

$$(21) \qquad mwh^*-B=[\hat{m}w-D]h^{***}$$

where $\hat{m}$ is the value of m under wage-subsidy scheme (c). It is evident from (21) that the x-ratio for the *NIT* is $x=B\,[[1-m]wh^*]$ and for the wage-subsidy scheme is $\hat{x}=D/[1-\hat{m}]w=B/[wh^{***}-wmh^*]$, so that $\hat{x}\gtreqless x$ as $h^{***}\lesseqgtr h^*$. However, from (9) and (18c) it can be shown that $h^*>h^{***}$ would imply $\hat{x}<x$ which is a contradiction. Hence $h^{***}>h^*$ once again.

Thus, under universal equivalence the level of labor incentives ranks the schemes in the following order: type (a) wage subsidy, type (c) wage subsidy, *NIT*.

B. *Expected Equivalence*

Suppose that instead of requiring equivalence under each state of nature we require only that *expected* disposable income, taxes or utility be the same in each case. Once again we may argue that wage-subsidy scheme (a) provides higher work incentives than does scheme (c) or the *NIT*. When we come to a comparison of scheme (c) and the *NIT*, however, the comparison is not so straightforward. For example, let us suppose that it is required that expected disposable income at the optimum be the same for each scheme. Clearly this requires

$$(22) \qquad vwh^*+[1+q]\bar{B}=[\hat{v}w+[1+q]D]h^{***}$$

where $Dh^{***}=\bar{B}$. Notice that there is only one constraint on the value of the tax parameters rather than the two constraints under comparison A. Hence, given $\hat{v}$ and D, it will in general be possible to choose a *NIT* scheme

with parameters v, B such that (22) is satisfied, $\hat{x}<x$ and $h^*>h^{***}$. Hence if only expected equivalence rather than universal equivalence is required we can *construct* a *NIT* with more favorable labor incentives but, in general, a different *MTR*.

C. *Marginal Comparisons*

So far I have considered simply the effect of a given set of tax parameter values on the *total* quantity of labor supplied. An important additional question concerns the *change* in labor supply in response to a small change in taxation. The motivation for this is easy to see. Suppose we design an anti-poverty program with some given level of transfer and marginal tax rate. Furthermore, suppose that it is subsequently decided that the *MTR* should be increased along with the guaranteed transfer in order to "direct public assistance more selectively"—that is, to increase the scheme's progressivity. We should be interested to know whether the particular administrative structure of the scheme will imply that such increases in the *MTR* will be accompanied by significant disincentives to work at the margin. For this comparison we are interested in the relative magnitude of a quantity such as $\partial h/\partial m$ at the optimum under the different schemes.

For ease of comparison, I examine the three schemes under a situation where each has an identical x-ratio, and consider the effect on optimum labor supply of a small increase in progression—that is, of an increase in this ratio of transfer income to disposable earnings. This can be done by examining z_x at the optimum, which provides a convenient way of representing the effect of an increase in the progressivity of the maintenance scheme upon labor supply.

Now it is evident from (19a), (19c) that $z_x^{**}=0$ and $\varepsilon z_x^{***}>0$. So if $\varepsilon>0$ an increase in x has a more favorable effect on incentives under wage-subsidy scheme (c) than under scheme (a); the reverse conclusion is true if $\varepsilon<0$. By using (10) a similar argument holds for a comparison of the *NIT* with the type (a) wage-subsidy scheme. There remains the comparison of wage-subsidy scheme (c) with *NIT*. From (19c) and (10) it is apparent that

$$z_x^{***} \gtrless z_x^* \text{ as}$$

$$(23)\quad q\varepsilon[1+1/x]^{\varepsilon-1} \gtrless \left[-x^2+q[1+1/x]^{\varepsilon-1}[1+x][\varepsilon-x]\right]$$

$$\text{or}\qquad q[1+1/x]^{\varepsilon-1}[1+x-\varepsilon]+x \gtrless 0$$

Hence, we expect that for low values of ε (risk aversion), wage-subsidy type (c) provides superior incentives to those of *NIT*; for large values of ε, the situation will be reversed. However, if q vanishes, then *NIT* always provides lower incentives at the margin.[18]

Finally, let us consider the case where the uncertainty relates to unemployment (type 4) and leisure is determined by relation (6). Once again we may compare the *NIT*, a wage subsidy with earnings-related unemployment benefit (case (b) of the last section), and a wage subsidy with flat rate unemployment benefit. As noted before, this last program turns out to have the same labor supply function as case (a) (see equations (18a), (19a)). From equations (9) and (10) it is clear once again that, except for marginal comparisons, this program will produce greater work incentives than either of the other two programs. Let us then consider the *NIT* versus a type (b) wage subsidy.

Clearly z_x is negative for the *NIT*, and from (19b) we know that it will be positive for the wage subsidy if $\varepsilon<0$. Hence we may infer that for low inequality aversion the wage subsidy provides greater work incentives than the *NIT*. This conclusion does not necessarily hold for high risk aversion.

Notice how the choice between the two wage-subsidy schemes depends on the way leisure is modelled under the different states of nature. If leisure is $l-h^*$ then an earnings-related unemployment compensation program elicits maximum work hours. If leisure is determined as equation (6), then a flat rate unemployment compensation is to

[18]The result in this limiting case concurs with the standard result regarding *levels* of work incentive under certainty established by, for example, Kesselman (1971, 1973).

be preferred. In each case the wage subsidy is preferred to the *NIT*, except for *marginal* comparisons when there is a positive probability of failure.

IV. Concluding Comments

In a simplified model we have seen how dramatically different results on taxation and labor incentives are found if wage uncertainty is present, because of the uncertainty-reducing role of the tax and income maintenance scheme. The phenomenon of greater progressivity producing increased work arises in each of the models of risky labor contracts we have considered for one or more of the income maintenance programs. Aside from the issues of comparison of the schemes (Section IV), what are the policy implications?

Clearly, redistribution and incentives may go hand-in-hand for some segment of the population regardless of the instrument used. This segment would be characterized by relatively high risk aversion, significant but not enormous wage risk, and not too high a ratio of nonemployment income to earnings. It would be interesting to know how these characteristics are distributed within the population—in particular the possible correlation of risk aversion and incomes. However, it seems that persons for whom the perverse results are particularly likely to hold will be the moderately poor with little income other than earnings (the very poor will have very low potential earnings and therefore high x-ratios), with fairly high income variability, and fairly strong aversion to risk (which may in turn depend on family size). If these groups can be identified in practice then the perverse incentive results may provide the basis for a valuable development in income maintenance programs.

Appendix

Let $U(c, h)$ be a concave utility function satisfying $U_c>0, U_h<0, U_c(0, h)=U_h(c, 1)=\infty$, and let $c=y-T$ where T and y are given by (1) and (2). Maximization of EU gives

$$\text{(A1)} \quad dEU/dh=vE(U_cW)+EU_h=0$$

for an interior solution. Write $\bar{w}\equiv EW$ and differentiate equation (A1). We get

$$\text{(A2)} \quad vE(U_{cc}W\,dc^*)+E(U_{ch}dc^*) + [vE(U_{ch}W)+EU_{hh}]\,dh=E(U_cW)\,dm$$

where $dc^*=vW\,dh-h^*W\,dm+dB$. Now if we put $E\,dc=0$, we have $dB=h^*\bar{w}\,dm-v\bar{w}\,dh^*$. Substituting in (A2) gives

$$\text{(A3)} \quad \left[v\left[E(U_{cc}W^2)-\bar{w}E(U_{cc}W)\right] + \left[E(U_{ch}W)-\bar{w}EU_{ch}\right]\right]\left[v\,dh^*-h^*dm\right] + \left[vE(U_{ch}W)+EU_{hh}\right]dh^*=E(U_cW)\,dm$$

Noting that $E(U_{cc}W^2)-\bar{w}E(U_{cc}W)=cov(U_{cc}W, W)$ and writing $Q=cov(W, U_{ch}+vWU_{cc})$, we find (A3) implies

$$\text{(A4)} \quad \left.\frac{dh^*}{dm}\right|_{E\,dc=0}=\frac{E(U_cW)+h^*Q}{vE(U_{ch}W)+EU_{hh}+vQ}$$

Secondly, if we put $E\,dT=0$, we have $dB=h^*\bar{w}\,dm-v\bar{w}dh^*$, which upon substitution in (A2) by a similar method yields:

$$\text{(A5)} \quad \left.\frac{dh^*}{dm}\right|_{E\,dT=0}=(E(U_cW)+h^*Q)/ (v\bar{w}E(U_{cc}W)+\bar{w}EU_{ch} +vE(U_{ch}W)+EU_{hh}+vQ)$$

Clearly if $Q=0$ the signs of (A4) and (A5) can be determined simply by the signs of their respective denominators. The sufficiency conditions for these to be negative turn out to be identical to the conditions for the case of certainty. Otherwise, the sign and magnitude of the covariance term Q will be crucial in determining the effect of tax progression. The sign of this clearly depends on the dispersion of W, the magnitude of $v\bar{w}$, and the "curvature" of the utility function—risk aversion. In particular, Block and Heineke show that the reasonable assumptions of declining absolute risk aversion, sep-

arable utility (implying that risk aversion is independent of total hours worked), and the superiority of leisure guarantee that Q is strictly positive. Hence it is clearly *possible* to get the perverse results of a compensated increase in progression leading to *greater* labor supply in a quite general model with a conventional utility function. The text identifies more carefully the conditions under which this arises in a more convenient special case.

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Is Unilateral Tariff Reduction Preferable to a Customs Union? The Curious Case of the Missing Foreign Tariffs

By PAUL WONNACOTT AND RONALD WONNACOTT*

During the past decade and a half, an important part of the literature on customs unions has dealt with the question of whether a country might obtain the gains it would achieve from a customs union (*CU*) in an alternative way, by a unilateral tariff reduction (*UTR*). (*UTR* may involve a partial reduction in tariffs, or a reduction all the way to zero.) A widely accepted conclusion (see Eitan Berglas, p. 329; C. A. Cooper and B. F. Massell, 1965b, pp. 745–47; Roma Dauphin, ch. 2; Harry Johnson, p. 280; Melvyn Krauss, pp. 417–19; and Peter Robson)[1] is that *UTR* does indeed hold out the prospect for all the gains from a *CU*—without the disadvantages—if two important simplifying assumptions are made; namely, that we ignore economies of scale and the effects of a customs union on the terms of trade.[2] In the words of Berglas: "It is important to note that if a [preferential] trade agreement does not affect the terms of trade, then it does not allow for any mutually beneficial policy opportunities which are not open to each of the member countries separately [through *UTR*]" (p. 329).

If this conclusion is correct, it is very important, in that it undercuts the earlier literature on customs unions. The question asked by Jacob Viner in his pioneering work—whether a *CU* represents a net gain or a net loss in economic efficiency—becomes unimportant, except insofar as a customs union is based on terms-of-trade effects[3] or economies of scale,[4] since a *CU* can be summarily rejected in favor of *UTR*. The *UTR* case would mean that, for economists, the puzzle is not to identify the efficiency gains (or losses) from a *CU*, but rather to explain why countries form customs unions in the first place (Berglas, p. 329; Cooper and Massell, 1965b, p. 247; and Johnson, p. 270). Indeed, in his survey of *CU* theory, Krauss identifies the problem raised by Cooper and Massell—of *why* countries form customs unions—as "...the theoretical issue of the past decade [the 1960's] just as in the prior one the major issue, as explicitly defined by Jacob Viner (1950), was whether a customs union represented a movement towards freer trade or greater protection" (p. 413). The typical reply to the Cooper-Massell question is: Countries tend to form a *CU* for noneconomic reasons (Berglas, pp. 329–30).[5]

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[1]The three primary articles are Berglas; Cooper and Massell, 1965b; and Johnson. The other works are surveys or elaborations of the primary articles.

[2]Johnson (pp. 274–82) discusses a third source of mutual benefit from a *CU*; namely, the existence of externalities in manufacturing.

[3]On terms of trade and customs unions, see Sven Arndt (1968, 1969); and Krauss (pp. 421–24).

[4]There has been a tendency in the *CU* literature, tracing back to Viner (p. 47), to dismiss economies of scale as unimportant (for example, see Krauss, p. 420). In our empirical work on North American free trade (1967), we concluded that economies of scale were much more important than the triangular welfare gains identified by traditional theory. In many cases, we question how enlightening it is to study a *CU* without considering economies of scale. Nevertheless, in this paper, we will stay within the traditional framework and ignore economies of scale, since we are studying a specific theoretical issue which has arisen in the literature. (On economies of scale and customs unions, see also W. M. Corden and John Williamson.)

[5]Johnson (pp. 258, 270, 279–81) explained why customs unions may be formed for a partly political reason. Specifically, he assumed that countries have a "...collective preference for industrial production..." (p. 258). Cooper and Massell (1965a) offer a similar rationale for the formation of customs unions among developing countries. Another argument for preferring a *CU* to *UTR* is that each member provides the other(s) with protection against third-country imports; this may

In this paper, our contention is that the *UTR* literature is not correct. (We believe that the earlier question raised by Viner—of the effects of a *CU* on efficiency—is the most important one, although the answers suggested by Viner were not completely satisfactory, as has been pointed out by such writers as Franz Gehrels; Richard Lipsey, 1957; and James Meade.) The *UTR* literature is fundamentally wrong, not in the sense of having made logical errors, but wrong in having begun from a series of assumptions—some explicit and some implicit—which in effect rule out the principal advantages of a *CU*. Suppose that we were to ask the average politician or business executive the $64 question raised by the *UTR* literature: "What economic advantage can there possibly be in forming a customs union?" The probable reply would be: "To get down the tariffs of our partners in the proposed customs union, and thus gain better access to their markets." It is therefore surprising that, in arguing the case for *UTR*, Cooper and Massell (1965b, p. 747) make only a concluding reference to market swapping, but conduct no analysis of the elimination of tariffs by the *CU* partner.[6] While this oversight is corrected elsewhere in the literature—most notably by Berglas—Berglas makes strong assumptions about Country *C* which mean that Country *A* cannot possibly gain from its newly acquired access to *B*'s markets. These include the implicit assumptions that Country *C* has no tariffs, and there are no transportation costs.[7] (We follow the standard terminology of two prospective *CU* partners, *A* and *B*, and an outside Country *C*. The establishment of a *CU* involves the elimination of tariffs on trade between *A* and *B*, and the adoption by *A* and *B* of a common tariff on imports from *C*.)

Our major contention is that, in a world in which tariffs and other obstacles to trade exist, it is meaningless to analyze the effects of freeing trade between *CU* members if we assume that there are no impediments to trade with outsider *C*. It is misleading to analyze a *CU*, and in particular to compare a *CU* and *UTR*, unless all countries are recognized to have tariffs to begin with. Anything else is Hamlet without the prince. In more detail, we argue that:

1) In making the case for *UTR*, its proponents make either or both of the following assumptions (explicitly or implicitly): (a) That partner *B*'s tariffs can be ignored. (b) That outsider *C* has no tariffs, and there are no transportation costs in trade with *C*.

2) If we depart from both of these assumptions, a country can achieve gains from a customs union which are not possible with *UTR*.

3) This conclusion, that the dominance of *UTR* over a *CU* collapses if we reject assumptions 1a and 1b, holds even if we make the standard assumption that there are no gains in the terms of trade with outside Country *C*. Furthermore, it collapses even if we assume that the terms of trade among the members of the *CU* remain unchanged as a result of the formation of the *CU*. (In practice, there is very little chance that the terms of trade will remain constant. However, we shall examine this case because it occurs in parts of the literature,[8] and also because there is some confusion over intraunion terms of trade.)[9]

sustain the demand for labor and reduce short-run unemployment and other dislocation costs associated with a change in commercial policy.

[6]Cooper and Massell's conclusion is based on demand and supply curves for a single good, the import of Country *A*. No analysis is made of *A*'s exports to *B*.

[7]These implicit assumptions may be found in Figure 1 and Table 1 of the Berglas article. In his Figure 1, Berglas has outside Country *C* importing only one good (commodity 2). The price of that good in Country *C* is shown in his Table 1 to be identical to its price P_2 in exporting Country *A*. This can be so only if no tariffs or transportation costs are added to the price of commodity 2 as it goes from *A* to *C*. (More generally, his Table 1 involves the assumption that there are no transportation costs on any trade.)

[8]For example, Berglas makes such an assumption; or, more precisely, he assumes that a country is committed to compensate a partner for any adverse change in its bilateral terms of trade.

[9]Most notably, Krauss in his survey (p. 417) states that Cooper and Massell assume that the home Country *A* is unable to affect its terms of trade because the partner *B* and third Country *C* are large. This conclusion is incorrect; a *CU* is *especially* likely to lead to an improvement in the terms of trade if the partner is a big country. See our point 4 which will be explained later

4) When a *CU* is being established, the terms of trade is a slippery concept; we should be careful to state propositions about terms of trade precisely. For example, the assumption that *A* is very small, and is faced by a large *B* and a large *C*, does not mean that terms of trade can be ignored, since *B*'s agreement to cut tariffs will affect *A*'s terms of trade. Indeed, an important reason for *A* to want to get rid of *B*'s tariffs is to be able, for the first time, to trade at *B*'s domestic terms of trade.

5) The standard assumption, that *A* is very small compared to *C*, is not so reasonable as it seems at first glance; in particular, it is not nearly so reasonable in a many-good world as it seems in the common two- and three-good models of trade theory. In fact, no outside country or group of outside countries is likely to be predominant in the pricing of all goods.

One further preliminary point should be clarified. In attacking the case that *UTR* offers all the gains of a *CU* (except for terms of trade and economies of scale), we are not arguing that *UTR* never dominates a *CU*. That would obviously be going too far. (For example, many countries with high tariffs could improve efficiency by *UTR*; and for such a country it would be easy to imagine a heavily diverting potential *CU* that would reduce efficiency. Therefore, we should be able without difficulty to find examples of potential customs unions which are dominated by *UTR*.) What we do dispute is that a *general* case has been made that "...a more efficient allocation of resources could not be the reason why customs unions are formed..." (Krauss, p. 417).

I. A Preliminary Puzzle

Before we turn to our five main points, let us look at an example—quite different in its details and assumptions from the literature we criticize—which shows the implausibility of the argument that *UTR* will provide all the gains from a *CU*, provided economies of scale and terms-of-trade effects are ignored. Consider a *CU* that would involve all the countries of the world except Nepal. Assume the special case where the *CU* would leave the terms of trade among members unchanged. For any member, such a *CU* would be essentially indistinguishable from worldwide free trade in the benefits it would provide. And any terms-of-trade effect with the third country (Nepal) would be trivial for the members of the *CU*. The *UTR* literature would have us believe that such a *CU* is no better than *UTR*. But surely there is something wrong here. For any member, this *CU* would offer essentially the same benefits as worldwide free trade, which in turn offers something that *UTR* doesn't: namely, the abolition of foreign tariffs. And the abolition of foreign tariffs is a clear and unambiguous advantage.[10] Somehow, somewhere, in coming to the wrong conclusion the *UTR* literature has made assumptions whose critical importance has gone unrecognized. Our task will be to explain the importance of these assumptions.

II. Reciprocal Gains from a Customs Union, with Terms of Trade Unchanged

In our example, with Nepal as outside Country *C*, we have eliminated the importance of terms-of-trade changes in a manner quite different from the *UTR* literature cited earlier. In order to bring our argument back toward the main body of *UTR* literature, we now make the more standard assumption: The *CU* partners live in a world in which outsider *C* is not small. Indeed, *C* is so large that its demand and supply functions appear

with Figure 4. (Actually, only Krauss, and not Cooper and Massell, made this error. Cooper and Massell assumed only that the third country is large, the partner is not.)

[10] Curiously, the comparison of *UTR* and *CU* led Johnson to argue that *multilateral* tariff reduction is no better than *UTR*. This argument of Johnson is considered in the final section of this paper. (On the face of it, Johnson's focus on the burden of the home tariff to the exclusion of foreign tariffs is puzzling. As Abba Lerner demonstrated, a 10 percent across-the-board import tariff is equivalent in equilibrium to an across-the-board export levy of the same height. But this in turn is equivalent to an across-the-board foreign levy on our exports, with one notable exception: the foreign government rather than the home government gets the revenue. Thus, there is a presumption that foreign tariffs create a greater burden than home tariffs of the same height.)

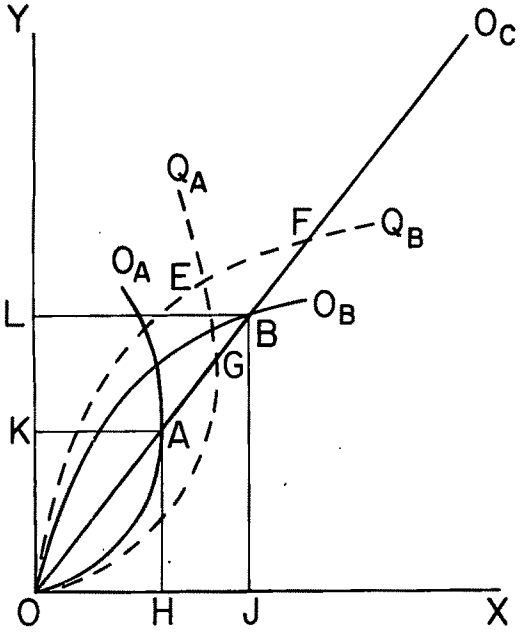

FIGURE 1. LARGE COUNTRY HAS NO TARIFFS OR TRANSPORTATION COSTS

perfectly horizontal to *CU* members *A* and *B*. In a two-commodity general equilibrium framework, *C*'s offer curve is a perfectly straight line.

In Figure 1, we derive the principal conclusion in the *UTR* literature (namely, that a *CU* offers nothing—apart from terms-of-trade improvements and economies of scale—that cannot be obtained through *UTR*).[11] We begin with the situation where *C* has no tariffs (although *A* and *B* do), and transportation costs between *C* and *CU* members are ignored. Not surprisingly, the offer curve of Country *C*, O_C has a dominant effect on international prices; *A* and *B* can trade any amount they like with *C* without affecting the relative prices given by the slope of *C*'s offer curve. Prior to the establishment of the *CU*, the offer curves of *A* and *B* are O_A and O_B, respectively. Country *A* trades at point *A*, exporting *OH* of good *X* in exchange for *OK* of *Y*, and Country *B* trades at *B*, exporting *OL* of good *Y* in exchange for *OJ* of *X*.

Now suppose that a *CU* is formed between *A* and *B*, with a prohibitive common tariff on imports from *C*. Their offer curves, as seen by the *CU* partner, will move to the dashed curves Q_A and Q_B. With the prohibitive external tariff, no trade will take place with Country *C*, and equilibrium between *A* and *B* will occur at point *E*.

From the point of view of Country *A*, its move from *A* to *E* represents an improvement. Moreover, *E* is better than Country *A* can do by unilaterally eliminating its tariff and thus moving to *G*. But *B* could do better by a simple unilateral elimination of its tariffs, moving to point *F*. While Country *A* is better off at *E* (with a *CU*) than at *G* (with unilateral free trade), it has the problem (noted by Berglas) of persuading *B* to join the *CU*. If, in order to induce *B* to join, *A* has to compensate *B* for the amount by which *E* is inferior to *F*, then Country *A* would be better off to move unilaterally to reduce tariffs. (With standard assumptions, it can be shown that Country *B*'s loss at *E* compared to *F* is greater than the amount by which Country *A* prefers *E* over *G*.) *UTR* dominates a *CU*. Indeed, within this framework, each partner should move all the way to unilateral free trade.[12]

(The country against which the terms of trade shift as a result of *CU*—Country *B* in our illustration—may be better or worse off as a result of a *CU* (at *E*) as compared to original point *B*, depending on the shapes and positions of the offer curves. But, in either case, it will be better off with a unilateral elimination of tariffs and a move to *F* than it would be with a customs union at *E*. Furthermore, in no case will Country *A* be able to "bribe" *B* to join a *CU* without itself ending at a position inferior to that obtainable through *UTR*.)

[11]In this paper, we use offer curves to explain our case. In the *UTR* literature, the standard analytic tool has been single product demand and supply functions, with welfare triangles being the center of attention. Thus, there is some danger that, in using a different theoretical framework, we are writing at cross purposes to the other authors. To make clear how our points fit into the theoretical framework of the earlier articles, we elsewhere (1980) review the literature, explain in more detail how the authors fall into the traps we allege, and repeat our arguments with single product diagrams.

[12]Thus, this offer-curve framework, like Cooper and Massell's single product analysis (1965b, p. 747), leaves the puzzle of why countries have tariffs in the first place.

The main feature of this *UTR* argument is that *C* is freezing the world terms of trade at the slope of O_C: *C* will buy or sell unlimited quantities of *X* or *Y* at the relative price shown by its offer curve. Consequently, *A* and *B* have nothing to gain collectively by trading with each other rather than with *C*. Prior to the *CU*, it is a matter of indifference to Country *B* whether it conducts *OA* amount of trade with Country *A* and the remaining *AB* with Country *C*, or whether its total trade of *OB* is with Country *C*. And a *CU* is not collectively beneficial for *A* and *B*, compared to nondiscriminatory tariff removal and trade with *C*; while one country (*A*) will prefer a *CU*, the other (*B*) will even more strongly prefer trade with *C*. (In the special case where *E* falls on O_C, there is no difference between the outcome with a *CU* and that with unilateral moves to free trade by Countries *A* and *B*.)

The question is: In the real world, do prospective members of a *CU* have anything to offer one another that is not readily available from the outside world? The answer is yes. But what? Consider the United Kingdom and Germany. What can they gain from trade with one another that they can't gain from trade with the United States? A partial answer: they may *each* be in a position to offer the other a better price than the other could get by trading with the United States. How can that be? Because, in trading (for example) steel for coal with one another, they don't have to pay the costs of transportation to and from the United States, nor do they have to pay *U.S.* tariffs. In other words, by trading with each other, they can both benefit by sharing their net saving on transportation costs and *U.S.* tariffs.[13] A major problem, therefore, with the *UTR* literature is that it is based on the assumption that outsider *C* is not only large but it has no transportation costs nor tariffs. As a consequence, this literature has missed the important way in which a *CU* can provide mutual benefit to its members.

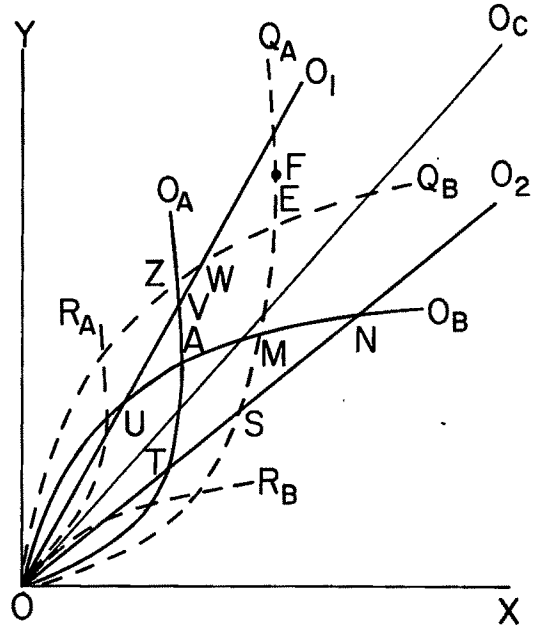

FIGURE 2. LARGE COUNTRY HAS TARIFFS AND TRANSPORTATION COSTS

The case where *C* has transportation costs and tariffs is shown in Figure 2. With this figure, we illustrate the point at issue; that is, the possibility that a *CU* can provide gains not possible through *UTR*. With the introduction of *C*'s transportation costs and tariffs, Country *C* now presents not one, but rather two, offer curves. While the relative prices within *C* remain at the slope of O_C, the offer curve of *C* as seen by *A* and *B* will be either O_1 (if *A* or *B* purchase *X* by exporting *Y*) or O_2 (if *A* or *B* purchase *Y* by exporting *X*).

Thus, *C*'s transportation costs and tariffs drive a wedge between *C*'s offer curves (just as they drive a gap between the domestic and world prices in a simple demand/supply model). If this wedge—defined by the angle between O_1 and O_2—is wide enough, so that *A* and *B* trade within it both before (at *A*) and after the *CU* (at *E*),[14] it is as though

[13] *Net* saving on transportation costs; that is, the saving from transportation costs to the extent that they are lower between the U.K. and Germany than they are between Europe and America.

[14] The question may arise as to why, prior to the *CU*, Country *A* would be satisfied with point *A*, and not try to pick preferred point *V* by trading with Country *C*. The answer is that point *V* is not an option open to Country *A*. Point *V* is on the offer curve O_1 where

Country C did not exist. Its overwhelming dominance over A and B's trade disappears. With C "out of the picture," the question of whether the rest of the world (i.e., countries A and B) should form a CU reduces to the standard two-country free-trade question. Thus, in this case a CU can easily be shown to be beneficial under standard assumptions; both countries have a higher welfare at E than A. Moreover, for each country, a CU dominates unilateral free trade: A has higher welfare at E than M, while B is better off at E than W.[15]

(We ignore transportation costs between Countries A and B. Adding them unnecessarily complicates the analysis without altering the conclusions—so long as the CU is made up of geographically close members, with internal transportation costs less than those with third countries.)

This example resolves two puzzles. First, how can the contention of UTR writers—that UTR is always at least as good as a CU—be correct if C has prohibitive tariffs, so that trade with C is not even an option for A and B? The answer is that the UTR contention is incorrect; C's prohibitive tariffs open up a sufficiently wide wedge between O_1 and O_2 to drive C out of the picture, as in Figure 2, thus leaving a CU as the preferred policy. The second is the Nepal paradox. Nepal is so small that its offer curves are indistinguishable from the origin; curves O_1 and O_2 in such a diagram don't appear. Once again, in choosing between A and E, the two CU members face the standard free-trade question.

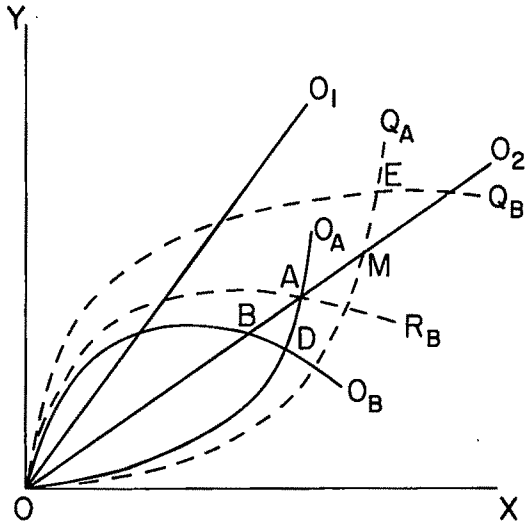

FIGURE 3. GAINS IN SPITE OF TRADE DIVERSION

A. *Gains with Trade Diversion*

Figure 2 presents an example of trade creation, where CU benefits are relatively easy to show. (An even simpler example would be the case where preunion tariffs of Countries A and B were high enough to completely prevent trade in these products, as shown by offer curves R_A and R_B.) However, our main point—that a CU may provide gains not possible through UTR—is valid also in the more complicated case of trade diversion (where diversion is defined simply as the shifting of the source of supply from outside Country C to partner B). This is shown with Figure 3.

Consider first the situation prior to a CU. Country A is such a large supplier of X that, if there were only bilateral trade with B, trade would take place at D. However, this price is lower than Country A can get from C; A therefore carries on some trade with C, at the after-transportation, after-tariff relative prices shown by the slope of O_2. Continuing our simplifying assumption that there are no transportation costs between countries A and B, we note that Country B chooses to trade with A at the relative set of

Country C exports X and imports Y. But Country A wants to export X and import Y. Because of tariffs and transportation costs, Country C is willing to import X and export Y only at a relatively high price for Y; that is, only at the relative prices given by offer curve O_2. Thus, in trading with C, Country A would end up at T, not V, and point A is clearly better for it than point T. Similarly, if Country B trades with C, it will end up at U, not N; and A is clearly preferred to U. Thus, Countries A and B choose trade with each other at point A, rather than trade with Country C at points T and U, respectively.

[15]If Country A unilaterally eliminates its tariffs, it still trades with Country B; its equilibrium with B (which still has tariffs) is at point M, and this is preferable to the point (S) that it could pick in trade with Country C. However, if Country B unilaterally removes tariffs, it will trade with C, since point W dominates Z.

prices which A offers in its trade with C; that is, the slope of O_2. Thus, prior to the CU, quantity OB of trade takes place between countries A and B, while BA takes place between countries A and C.

After the CU is established, trade takes place at point E. Countries A and B now trade only with one another; diversion of BA of trade has taken place.

The question is, how does each country compare the CU outcome with UTR? Consider first A's options. Unilaterally, A can improve its situation by eliminating tariffs, moving to point M. (The case here is the same as for unilateral free trade in Figure 1.) Clearly, for Country A, point E is better than UTR point M; a CU dominates UTR.

For Country B, unilateral gains are possible by a partial tariff cut which rotates its offer curve to R_B and increases its trade by BA.[16] Through negotiation of a CU and thereby reciprocal tariff elimination with Country A, Country B can achieve a further move from point A to E. We cannot be certain that E is superior to UTR point A from Country B's viewpoint: M is better than A, but E may be either superior or inferior to M, depending on the elasticity of Q_A. But our principal point holds: for Country B, point E *may* be superior to A (if Q_A is highly elastic and/or distance AM is large). Thus, for all members, a trade-diverting CU may represent a gain compared both to the original equilibrium, and to the options open under UTR.

Following the literature cited in our first paragraph, we have focused here on changes in welfare of the members of the CU. For these two countries, it does not matter whether the wedge between O_1 and O_2 is caused by tariffs or transportation costs. (More precisely, it does not matter provided that C's tariffs are fixed, and not open to negotiation.) However, if we consider world welfare, it does matter. A wedge caused by transportation costs involves the use of productive resources, and in this case a CU which improves the welfare of the member countries also improves world welfare. But insofar as the wedge reflects C's tariffs, a CU may mean a less efficient allocation of world resources, even though Countries A and B both gain. Specifically, the diversion of trade BA away from Country C in Figure 3 involves the loss of tariff revenues by C. In any worldwide welfare calculation, this loss must be weighed against the gains of the member countries.

Several loose ends remain to be tied up: the complications raised by the existence of more than one outside Country C; the existence of more than two goods; and ambiguities and confusions regarding the terms of trade.

III. Many Outside Countries

If A and B are trading with C, and C is a single large country, its tariffs are borne by A and B; the prices at which A or B can sell to C are reduced by the full amount of C's tariffs, and the full amount of C's tariffs (together with transportation costs) shows up in the gaps between O_C and O_1 and between O_C and O_2. In a more realistic case, where there are many outside countries, the situation is more complex, with the tariffs of outside countries falling partly on domestic consumers and partly on trading partners. In this case only part of an outside country's tariffs show up in the wedge in Figure 2. Indeed, it is conceivable that, if there are many outside countries operating in a highly competitive international marketplace, the tariffs of each of these countries will fall completely on their own consumers, and will have no effect on international prices at all. (This seems to be the implicit assumption of much of the literature.) But even in this case, there is a wedge because of transportation costs to and from outside countries; or, more precisely, because of higher transportation costs with outside countries than between members of the CU.

Our analysis of this wedge illustrates the obvious (but frequently ignored) reason why

[16]As we noted earlier in fn. 14, Country B can export good Y to Country C in exchange for X only at terms of trade O_1 because of C's tariffs and transportation costs. B can exchange at terms of trade O_2 only in trade with Country A. And, in the absence of reciprocal tariff cuts by Country A, the quantity of trade at such relative prices is limited to OA.

a *CU* usually includes geographically close countries, and excludes distant ones. Distance opens up the terms-of-trade wedge with outside countries, thus allowing mutually beneficial trade to take place between the members. Thus, this analysis raises doubts about the desirability from an efficiency viewpoint of geographically dispersed preferential systems such as the old British Commonwealth, where intermember transportation costs were generally no lower than transportation costs with third countries. (Of course, transportation costs are not the only thing to be considered when evaluating such an arrangement.)

IV. Many Goods

While offer curves provide a great advantage in drawing attention to general-equilibrium issues, they suffer from the severe limitation that only two goods can be considered. Logically, the offer curve analysis might be seen as involving N commodities in an N-dimensional space. But the problem is that a two-dimensional diagram like Figure 2 cannot be used to describe just two of the goods (X, Y) in an N-good world. In a two-good world, the exports of X will equal the imports of Y in equilibrium, but there is no presumption in an N-good world that the exports of any particular good, X, will equal any particular import, Y.

Faced with this problem, we depart from the formal model to offer some impressionistic conclusions regarding the plausibility, in a many-good world, of the common assumption that the terms of trade with the large third country are unaffected by A and B's tariffs. In a many-good world, even a huge country may not produce large amounts of every product. After all, even moderately sized single countries at present have substantial influence over the market of particular goods (Saudi Arabia in oil, Brazil in coffee, Canada in wheat). Thus, it seems implausible to see outside Country C as predominant in all commodities, and we must therefore question the rigid *UTR* assumption that C freezes the world terms of trade. For example, it is difficult to argue that the rest of the world could offer fixed terms of trade to a South American *CU*. However, in order to directly address the *UTR* case on its own grounds, we have assumed in Figure 1 that C's offer curves do reflect fixed terms of trade, and we continue to make that assumption (together with the companion assumption that there are no economies of scale).

V. Further Terms of Trade Issues

We now consider how a *CU* may affect the terms of trade between members A and B. First, observe that we have drawn Figure 2 so that the terms of trade between the two members are the same at E as at point A. This illustrates our main contention: Each country (A and B) can obtain gains from a *CU* which it cannot achieve unilaterally, even if the *CU* does not change the terms of trade between members within the union, or between the union and outside Country C. Of course, as we noted earlier, there is little chance that the terms of trade between A and B will in fact remain exactly the same. But even where there is some deterioration in the terms of trade of one of the partners, that partner may achieve gains from a *CU* which are not available through *UTR*. This was just shown with Figure 3, in the comparison of points E and A from Country B's viewpoint. And it shows up even more strongly in Figure 2, if Q_B is redrawn to intersect Q_A at point F. Although the *CU* results in a deterioration in B's terms of trade as the equilibrium moves from A to F, it provides benefits not possible through unilateral free trade (for the same reason that E dominates W).

The second point is that, even if we assume that B is a large country, presenting Country A with an infinitely elastic offer curve, A can still have a terms of trade change and a gain from a *CU*. Indeed, A's gain will come precisely because its terms of trade improve as a result of B's tariff elimination, as illustrated in Figure 4.[17] The elimination of tariffs by B will cause its offer curve to rotate counterclockwise from O_B to Q_B, giving A better terms of trade and higher

[17]For more detail, see Lipsey (1970, pp. 88–89).

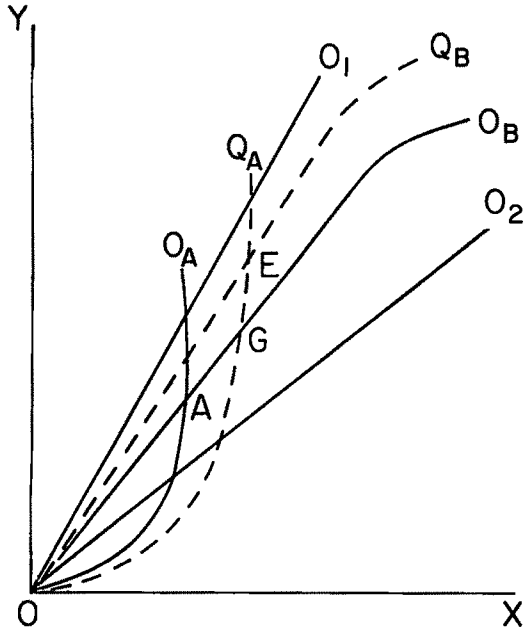

FIGURE 4. COUNTRY *B* MUCH LARGER THAN COUNTRY *A*

real income at *CU* point *E* than at original point *A*. This equilibrium *E*—which represents a Pareto optimum (provided that Country *C*'s policy is taken as a given not subject to change)—is not achievable through unilateral tariff moves, since Country *B* has nothing to gain by removing its tariffs unilaterally. (They are borne by foreign rather than domestic consumers.) But it will be in the collective interest of countries *A* and *B* to get to point *E* by forming a *CU*; Country *A* will be able to compensate *B* for the establishment of a *CU* if *B* makes this a condition for agreement. Thus, optimum point *E* may be achievable through bilateral (customs union) bargaining.

Finally, we should be careful in fitting the terms of trade issue into the overall case for a *CU*. Returning to Figure 2, we note that, while the terms of trade do not change between the preunion point *A* and postunion point *E*, the terms of trade are not rigid; they can be changed by national action. For example, if, instead of forming a *CU*, Country *A* unilaterally eliminates its tariff, this will result in a deterioration in its terms of trade with the movement to point *M*. The terms of trade gain for *A* when *B* also agrees to eliminate tariffs[18]—causing a move from *M* to *E*—will, in this special case, exactly offset the terms of trade loss from *A*'s initial move (and will leave each *CU* partner with a higher welfare than at initial point *A*).

The need for care in dealing with terms of trade issues becomes apparent if we consider a passage in which Johnson referred to the terms of trade in evaluating the relative merits of *UTR* and tariff bargaining:[19]

> ...the form and logic of bargaining for reciprocal tariff reductions [are] phenomena which are incomprehensible to the classical approach to tariff theory, according to which the source of gain is the replacement of domestic production by lower-cost imports, whereas *increased exports yield no gain* (*improved terms of trade apart*) to the exporting country, but a gain to the foreigner through the same replacement of domestic production by lower-cost im-

[18]Recognition of how a partner's tariff elimination may improve the terms of trade is important in disposing of another long-held belief—that when Country *A* diverts trade from outsider *C* to partner *B*, it necessarily incurs a terms-of-trade loss because it is no longer buying from the cheapest source *C*. (Lipsey and others have correctly pointed out that it will get a production and consumption gain, and the discussion has focused on how these two gains compare with the terms-of-trade loss.) However, there may not be a terms-of-trade loss at all; there may be a gain. Partner *B* may all along have been the cheapest free-trade source. But if this was the case, why wouldn't *A* have bought from *B* in the first place, before the *CU*? The answer is: *B*'s tariff may have prevented such trade. To illustrate, consider the following extreme case: Suppose *B* is the lowest-cost free-trade source, but *B* has imposed a prohibitive tariff that has precluded trade with all countries. Accordingly, *A* has been driven to trade with a less protectionist country, *C*. But if *A* and *B* form a *CU*, *A* will now trade with *B*, its lowest-cost free-trade source. (In less extreme cases, this same result may occur if *B*'s initial tariff is higher than *C*'s and sufficiently so to have choked off *A*'s natural initial trade with *B* and replaced it with trade with *C*.) In such circumstances, a failure to see beyond its own tariff could lead *A* erroneously to presume that *C* is its lowest-cost source. In this case, a *CU* is *A*'s means of diverting imports from a higher-cost source (outsider *C*) to its reciprocally cheapest source, *B*.

[19]Johnson applied this argument both to customs union bargaining and to multilateral, most-favored-nation bargaining.

> ports. Since these gains are attainable by unilateral action, the classical approach provides no explanation of the necessity and nature of the bargaining process. [p. 270, emphasis added]

A problem in interpreting this argument is an ambiguity in the passage we have italicized. If it is interpreted to mean that there can be no gain unless terms of trade change, then Johnson was wrong, as we have seen from our comparison of points A and E in Figure 2.

But there is a second possible interpretation of the italicized passage. Johnson may have been comparing points M and E in Figure 2 from Country A's viewpoint.[20] That is, he may have been saying that there is no gain to A from a reduction in B's tariff, if we ignore any change in the terms of trade associated with that reduction. But this interpretation makes Johnson's statement vacuous. *The* economic objective of A in negotiating foreign tariff cuts is to increase the demand for its exports. This involves a rotation in B's offer curve, and an improvement in A's terms of trade.[21] Johnson's argument that there is nothing, improved terms of trade apart, to be gained from foreign tariff cuts amounts to the proposition that there is nothing to be gained if the foreign offer curve is unaffected. But this means that the foreigners had no tariff to begin with. This is not a very enlightening line of argument. In brief, our plea for care in stating terms-of-trade issues is related to our plea that foreign tariffs not be implicitly assumed away in comparing *UTR* with a *CU*.

[20]This second interpretation is apparently what Johnson had in mind. See the later passage in Johnson where he argued that the case for a *CU* rather than *UTR* "...must rest on the possible terms-of-trade loss from unilateral tariff reduction and on the possible terms-of-trade gain for the union as a whole from discrimination against the outside world" (p. 280).

[21]There are two possible exceptions to the proposition that the rotation of B's offer curve will improve A's terms of trade: a) If there is a dominant third country, as explained with Figure 1. b) If Country A itself has a perfectly elastic offer curve. (In this instance, the *UTR* case is undercut, since A's tariffs fall on foreigners, not on domestic consumers.) The context of Johnson's passage makes it clear that he was not depending on either of these exceptions.

This paper demonstrates that *UTR* need not dominate a *CU* from an economic viewpoint. The proposition that *UTR* is dominant was based on an overemphasis on the cost-reducing effects of a country's own tariff reductions, and an underemphasis on the advantages in terms of the better access to foreign markets which follows the partner's tariff reductions. Once foreign tariffs are taken into account, there is no further reason for subscribing to the idea that *CU*s tend to be formed exclusively for noneconomic reasons. Such reasons may be present, and may be very important. But economists need not dismiss economic motives; in our view, the economic consequences of customs unions is a promising field for research.

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Cost-Benefit Analysis under Uncertainty

By DANIEL A. GRAHAM*

The implications of uncertainty for cost-benefit analysis remain controversial. Two related problems are the subject of this analysis. First, for any given future period, a dollar magnitude must be identified which appropriately represents the value of the uncertain benefits (costs) to accrue in that year. Second, an appropriate discount rate for converting this future value into present value must be identified.

For illustrative purposes consider a simple problem. The construction of a dam is being considered. Potential benefits include flood control in wet years and the provision of irrigation water in dry years. A standard approach to determining the value of this dam employs the probabilities of wet and dry years together with the value of benefits to accrue under each circumstance to calculate the expected value (mathematical expectation) of benefits in each year. Thus, for example, if there were two possible states of nature within a given year—"wet" and "dry" with probabilities .7 and .3, respectively, and if a particular farmer were willing to pay up to $50 for the dam if a wet year were certain and up to $100 if a dry year were certain, then $65 would be counted as the value of benefits accruing to the farmer in the given year. Adding across affected individuals would then yield the total benefit for the year.

Having obtained a measure of the total value of the dam within each year, the standard approach then involves discounting these benefits to obtain the present value, with the discount rate to be selected so as to appropriately reflect the riskiness of the benefits. Needless to say, there has been considerable controversy regarding the appropriate discount rate.[1]

In addition to the debate regarding the discount rate, there has recently surfaced a second controversy regarding the use of expected value as a measure of benefit within a period. If the farmer in the example were willing to pay $50 for the dam contingent upon the occurrence of the state "wet" and $100 contingent upon "dry," what is the maximum sure payment that he would be willing to make in both states? Following Burton Weisbrod, the term "option price" has been used to describe this maximum sure payment. Millard Long asserted that option price is nothing more than the expected value of surplus of $65 in our example. Cotton Lindsay disagreed, the Charles J. Cicchetti and A. Myrick Freeman III and then John Krutilla et al. argued that option price should generally exceed the expected value of surplus so that in our example the farmer should be willing to pay more than $65 to insure the availability of the dam. More recently, Richard Schmalensee and Claude Henry have shown that option price depends upon individual preferences and may either exceed or be less than the expected value of surplus. This result is, of course, troublesome for the analyst wishing to employ cost-benefit analysis. Having available estimates of the expected value of surplus for the farmer as well as his option price, which number is to be used as a measure of his benefit for the period? To what extent does the answer to this question affect the choice of the appropriate discount rate?

In what follows, I provide a conceptually correct procedure for determining whether a risky project passes the "potential Pareto improvement" welfare criterion which forms

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[1]See, for example, the discussion in Kenneth Arrow and Robert Lind.

the normative basis of cost-benefit analysis. In this approach the role of secondary markets in providing opportunities for redistributing risk is made transparent and the modifications necessary when such markets do not exist are suggested. Some of the more interesting results include:

1) Option price is the appropriate measure of benefit in situations involving similar individuals and collective risk.

2) Expected value calculations are appropriate to situations involving similar individuals and individual risks.

3) Whether or not option price exceeds the expected value of surplus is largely irrelevant to the evaluation of risky projects.

4) In a wide range of circumstances, including incomplete markets, discounting for risky projects should be done at the riskless rate.

I. The Willingness-to-Pay Locus

To gain insight into the appropriate measure of uncertain benefits within a given period, I shall continue the example of the dam. To make matters more precise, suppose there are two goods, the first of which will be called "dollars" while the second is the proposed dam. As before there are two possible states of nature, wet and dry with probabilities .7 and .3, respectively. Following the state-preference approach of Arrow, let us suppose that the farmer is endowed with claims to the first good contingent upon which state occurs: e_W dollars to be received if wet occurs and e_D dollars if dry. Using the von Neumann-Morgenstern theorem as extended by Jack Hirschleifer, the farmer's utility function can be represented as

$$U=.7U_W(c_W,\delta)+.3U_D(c_D,\delta)$$

where c_W and c_D represent claims to dollars contingent upon wet and dry, respectively, and δ depicts the availability of the dam ($\delta=1$ indicates that the services of the dam are available to the farmer under specified terms and $\delta=0$ indicates that they are not).

The standard assumptions are made that

Nonsatiation: $$U_i'(c_i,\delta)\equiv\frac{\partial U_i}{\partial c_i}>0 \qquad i=W,D$$

Risk Aversion:[2] $$U_i''(c_i,\delta)\equiv\frac{\partial^2 U_i}{\partial c_i^2}<0 \qquad i=W,D$$

The terms "expected surplus" and "option price" may now be made precise. Define S_i, $i=W,D$ by the requirement

$$(1)\qquad U_i(e_i-S_i,1)=U_i(e_i,0);\quad i=W,D$$

Then the expected surplus is

$$(2)\qquad E(S_i)\equiv .7S_W+.3S_D$$

[2]There seems to be some confusion in the literature regarding the meaning of the term risk aversion; see, for example, Schmalensee, p. 815. The assumption as stated is sufficient to assure that the farmer would decline any fair, independent gamble. Suppose, for example, that given his endowment e_W, e_D he were given the chance to make any fair bet he wished on the toss of a (fair) coin. Supposing the outcome of the coin toss to be distributed independently of the states wet and dry, we have four states: "wet and heads," "wet and tails," etc. Let the bet pay x if heads and y if tails with $.5x+.5y=0$, then the utility of accepting the gamble is

$$\hat{U}\equiv .7[.5U_W(e_W+x,\delta)+.5U_W(e_W+y,\delta)]$$
$$+.3[.5U_D(e_D+x,\delta)+.5U_D(e_D+y,\delta)]$$

while the utility of declining the bet is

$$\bar{U}\equiv .7U_W(e_W,\delta)+.3U_D(e_D,\delta)$$

But risk aversion and $x,y\neq 0$ imply that

$$.5U_i(e_i+x,\delta)+.5U_i(e_i+y,\delta)<U_i(e_i,\delta);\quad i=W,D$$

Thus $\hat{U}<\bar{U}$ and the bet would be declined. On the other hand, gambles which are not independent of existing risks afford the individual an opportunity to buy insurance. It would surely be a misnomer to define risk aversion in a way that requires an individual to refuse the chance to buy fair insurance against an existing risk, and yet, this is the definition Schmalensee proposes.

Option price, on the other hand, is defined by the requirement:

(3)

$$.7U_W(e_W - OP, 1) + .3U_D(e_D - OP, 1) = \bar{U}$$

where $\bar{U} \equiv .7U_W(e_W, 0) + .3U_D(e_D, 0)$

Option value is defined as the difference

(4) $$OV \equiv OP - E[S_i]$$

We may now introduce a concept which will prove crucial to subsequent analysis. The "willingness-to-pay locus" consists of ordered pairs (γ_W, γ_D) satisfying

(5)

$$.7U_W(e_W - \gamma_W, 1) + .3U_D(e_D - \gamma_D, 1) = \bar{U}$$

where $\bar{U}$ is defined in equation (3). By construction, the farmer would as soon make any of the contingent payments (γ_W, γ_D) for the dam as do without it. Notice, moreover, that the previously defined magnitudes S_W, S_D and OP correspond to particular points along this willingness to pay locus, that is,

$$(\gamma_W, \gamma_D) = (S_W, S_D) = (\$50, \$100)$$

is one point on the locus, and

$$(\gamma_W, \gamma_D) = (OP, OP)$$

is another. This is illustrated in Figure 1. The concavity which is illustrated for the locus follows directly from the assumption of risk aversion.

A further point along the locus which might be called the "certainty point" may be identified for expository purposes. Let (γ_W^*, γ_D^*) be that point on the locus satisfying

(6) $$U_W(e_W - \gamma_W^*, 1) = U_D(e_D - \gamma_D^*, 1)$$

Were the farmer to contract for these contingent payments for the dam he would be indifferent as to which state of nature occurs. Put somewhat differently, he would have, in the process of contracting for these contingent payments, simultaneously acquired a completely insured position against the uncertain state of nature.

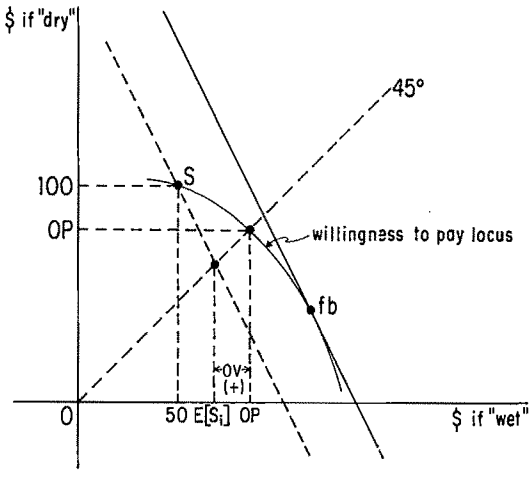

FIGURE 1

Finally, let the "fair bet" point (γ_W', γ_D') be that point along the locus which has the largest expected value. While precise relationships among the surplus, certainty, and fair bet points can be developed, here it is sufficient to point out that they are, in general, distinct points along the willingness-to-pay locus.

II. Option Value

The willingness-to-pay locus can be used to indicate the factors determining whether option value (equation (4)) is positive or negative. One possibility is illustrated in Figure 1. Here the fair bet point lies to the right of the 45° line. Since the slope of the locus at this point gives the relative probability of wet versus dry, a parallel through the surplus point S yields all payment combinations with the same expected value as the surplus point. Where this line crosses the 45° line, payments are equal in both states and thus also equal to the expected value of surplus. Here option price necessarily exceeds the expected value of surplus and thus option value is positive.

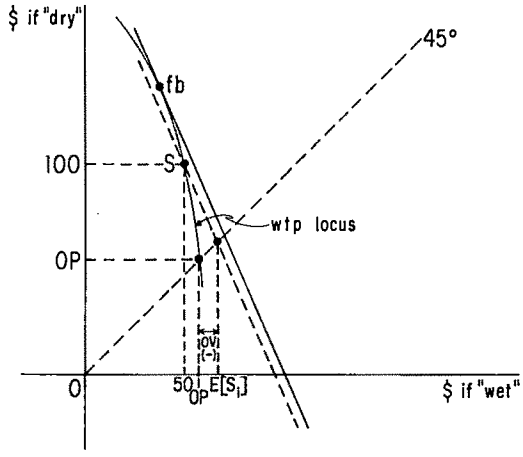

FIGURE 2

In Figure 2 the fair bet point lies to the left of the surplus point and a similar construction reveals that, in this case, the expected value of surplus must exceed option price yielding a negative option value.

A third possibility is that the fair bet point lies between the 45° line and the surplus point. Here there is ambiguity: option price may be greater or less than the expected value of surplus.

III. The Potential Pareto Improvement Test

Figures 1 and 2 not only summarize the considerations affecting the sign of option value, they also suggest that there may be little to recommend either option price or expected surplus for a role of prominence in cost-benefit analysis. They are, after all, only two arbitrarily selected points along the willingness-to-pay locus and have no obvious claim to preference over other points along the locus including the fair bet and certainty points. The question to be resolved ultimately is whether or not there exists payments for each individual which, when aggregated, yield sufficient resources to build the dam and which, when coupled with the provision of the dam, leave no individual worse off than he would otherwise have been. This question can be answered as follows. Having developed the idea of the willingness-to-pay locus for one individual, let us suppose that there are N people in the society and that the willingness-to-pay locus of the ith person is given by

$$\gamma_D^i = f^i(\gamma_W^i) \qquad i=1,\ldots,N$$

The method of aggregating these curves is illustrated for N equal to 2 in Figure 3 and will immediately be recognized as analogous to the "community indifference curve" construction from international trade theory. The curve labeled wtp_1 represents the willingness-to-pay locus of the first person. Similarly wtp_2 represents the locus of the second person.

The aggregate locus is obtained as the outer envelope of the set obtained by adding points from wtp_1 to points from wtp_2. Point C, for example, results from adding points A and B. Point C also represents the maximum sure payment that this "society" would be willing to make for the dam, and represents the magnitude that should be compared with a sure resource cost of building the dam. Should the cost of the dam itself be uncertain, no appreciable difficulty is added. If, for example, the cost is to be f_W in the state wet and f_D in the state dry, then the dam should be built on the potential Pareto improvement criterion since reference to Figure 3 indicates that society would be willing to sacrifice resources sufficient to cover actual costs in each possible state. (These are points on the aggregate locus to the northeast of F.) On the other hand, if resource costs are described by a point such as G which lies above the aggregate locus, then there does not exist a Pareto improving way of providing the dam.

It should be noted that if an aggregate payment such as C were actually collected with each person making a payment along his own willingness-to-pay locus, then a Pareto efficient distribution of risk would result. To see this, notice first that the slope of the aggregate locus at C is the same as the slope of each individual's locus at the implied payments points. But the slope of an individual's willingness-to-pay locus at a particular payments point is equal to his mar-

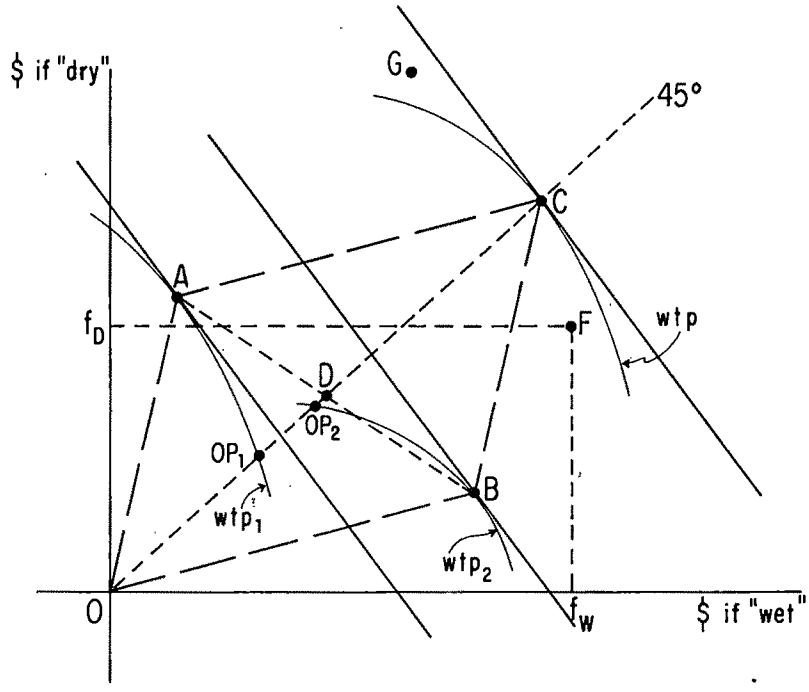

FIGURE 3

ginal rate of substitution between the two goods once the payments are contracted. Thus the marginal rates of substitution between "dollars if wet" and "dollars if dry" are equated for all individuals. Such a taxation scheme, therefore, is equivalent to establishing competitive markets for contingent dollar claims against the two states with relative prices equal to the common marginal rate of substitution.

This, then, is the general answer regarding which of the points along the individual's willingness-to-pay locus is relevant to cost-benefit analysis. For each possible pair of contingent claims prices for the two states, select that payment combination for each individual which has the greatest value at these prices. Adding these payments across individuals yields a point on the aggregate willingness-to-pay locus. Justification of the project hinges upon the question of whether or not contingent prices exist at which aggregate willingness to pay in each state exceeds the corresponding resource cost of the project. Should such prices exist, that point from an individual's locus which has the greatest value at these prices is the one relevant for cost-benefit analysis, and the corresponding value at these prices is the appropriate measure of benefit.

IV. Special Cases

It remains to determine whether option price or expected value calculations have any potential relevance to cost-benefit analysis. Consider first a special case in which 1) the resource cost of the dam is certain and 2) all individuals are alike—same utility functions and same endowed claims. Here we are concerned with the intersection of the aggregate locus with the 45° line since this point represents the largest possible sure payment. But, with all individuals alike, this aggregate payment entails each individual making a payment corresponding to the intersection of his individual willingness-to-pay locus with the 45° line. This payment, moreover, is simply the individual's option price. With individuals alike, the initial distribution of risk is

efficient and collecting the sure, option-price payment from each preserves this efficiency. Under these circumstances option price is the appropriate measure of benefit.

The second type of special case to be considered involves the concept of "individual risks" discussed by Edmond Malinvaud. The dam problem involves a "collective risk" since everyone will experience the state wet or everyone will experience the state dry. Consider an alternative situation based upon an example from Schmalensee. Here an individual can be in one of two "individual states." In the first he will have "a strong desire" to go to Yellowstone Park next summer. In the second he will have no desire to go. What is different about this situation is that it is possible for one person to experience "individual state 1" while another experiences "individual state 2."

It is possible, of course, to place this problem within the original framework by identifying states of nature according to the experience of each individual. Thus "state 1" might correspond to the situation in which each of the N members of society experiences individual state 1. Similarly, "state 2" might denote the case in which everyone except the Nth person experiences individual state 1 while the Nth experiences individual state 2. By expressing each person's willingness-to-pay locus in terms of contingent dollar claims against each of the 2^N possible states it is possible to proceed exactly as before.

A considerable simplification is possible, however, if we assume 1) again that individuals are alike and have the same endowments (the same individual state 1 and individual state 2 utility functions and the same endowed claims to dollars contingent upon these individual states), and 2) that the probability distribution of states takes a particular form. For simplicity, suppose that N is large and that the probability can be taken to be one that a total of $.3N$ individuals will be in individual state 1 in a given period and $.7N$ will be in individual state 2. While it is known with certainty what fractions of society will experience the alternative individual states, the fates of particular individuals are uncertain.[3] For any given person we simply suppose that the probability that he will be in individual state 1 is .3 while the probability of individual state 2 is .7. The willingness-to-pay locus of a representative individual is illustrated in Figure 4. The surplus point S indicates that the individual would be willing to pay up to $100 above the costs of the trip for a visit to Yellowstone if he were certain of individual state 1 and nothing if individual state 2 were certain. This yields an expected surplus of $30.

As previously mentioned, the discussion in Schmalensee focuses upon whether or not the individual's option price exceeds $30. Here we will be concerned with the implications of individual risks. The fair bet point (labeled *fb* in Figure 4) represents that point where the slope of the locus equals (in absolute value) the odds of being in individual state 1. The tangent to the locus at this point, then, represents alternative payment combinations with the same expected value. Since individuals are alike each is willing to make payments of Oa "$ if individual state 1" and Ob "$ if individual state 2." The expected value of these payments is OV for each person. Moreover, since it is known that $.3N$ individuals will experience individual state 1 while $.7N$ will experience individual state 2 the aggregate payment resulting from these individual payments would be

$$.3N \cdot Oa + .7N \cdot Ob = (.3 \cdot Oa + .7 \cdot Ob)N$$

$$= OV \cdot N$$

Thus it is possible to collect an aggregate sure payment equal to N times the expected value of the fair bet point. Since no larger sure payment is possible, the fair bet point may, in these circumstances, be identified as the one appropriate to cost-benefit analysis. In this case, the expected value of the fair bet point is the appropriate measure of benefit.

This special case is an illustration of a more general proposition developed by

[3]This situation is analogous to knowing how many wrecks will occur on the fourth of July weekend without knowing who will have them.

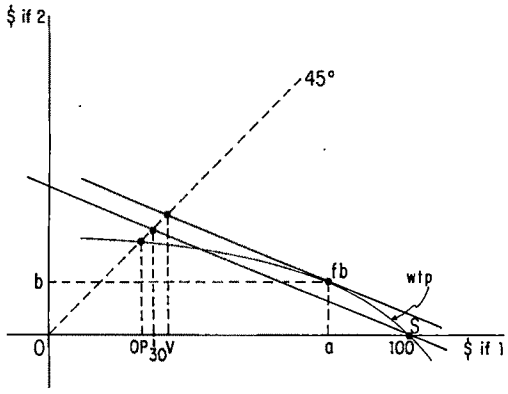

FIGURE 4

Malinvaud which indicates circumstances in which equilibrium prices for contingent dollar claims against alternative states tend to be equal to the probabilities of the states. The simplified procedure followed in this case is made possible, in essence, by the knowledge that prices equal to the probabilities of the individual states will yield an efficient distribution of risk. Reference to Figure 4 indicates that this case is further characterized by the fact that the expected value of surplus, $30, is greater than option price and, therefore, option value is negative. It would obviously be easy to illustrate a case in which option value is positive simply by drawing the willingness-to-pay locus so that it crosses the 45° line above $30. The sign of option value is, however, irrelevant. If expected values are relevant at all, that is, if the situation involves individual-insurable risks, then the expected value of the fair bet point is the largest of all points along the locus and is, therefore, the appropriate measure of benefit. If the situation does not involve individual insurable risks then prices which support an efficient allocation of contingent claims will not in general be equal to probabilities and expected values have no bearing upon the appropriate "market price" value.[4]

To restate, if individuals are alike, then option price measures benefit in cases of collective risk while expected willingness to pay (the expected value of the fair bet point) measures benefit in cases of individual insurable risks.

V. Second Best Considerations

The "hypothetical compensation test" of Kaldor, Hicks, and Scitovsky is the normative basis of cost-benefit analysis as it is normally applied. In this approach it is sufficient for the justification of a project that a set of payments be identified for a project which 1) individuals would willingly make for the project rather than do without it and 2) cover the actual costs of the project. It is not commonly required that a taxation scheme be identified which collects from each individual payments commensurate with his willingness to pay. Thus actual financing of a justifiable project may collect an amount exceeding benefits from some individuals and an amount less than benefits from others. In such cases it is simply argued that the winners could, in principle, compensate the losers.

The issue of the actual method of financing a project assumes a more crucial role in cases of uncertainty for reasons which will soon be apparent. Consider once again the situation illustrated in Figure 3. Here a society consisting of two people (who face a collective risk regarding the occurrence of state wet or state dry) is willing to make an aggregate sure payment corresponding to point C for a particular project. Suppose that actual financing of the project entails a sure collection of D from each ($C=2D$). This yields a surprising situation in which both people are worse off than they would have been without the project since D exceeds the

[4]Estimates of option price and the expected value of surplus may, of course, be used as lower bounds for the expected value of the fair bet point. It should be noted in this regard that an estimate of consumer's surplus (the Hicksian compensating variation) derived from demand data for Yellowstone visitors would ideally estimate the expected value of surplus. To see this note that since $.3N$ individuals visit the park each period with each having a surplus of $100, one would obtain 30N$, the aggregate expected value of surplus, from an ideal "area under the demand curve" type calculation. Since this measure is a lower bound for the true value, John Krutilla et al. were correct in their suspicion that expected surplus understates the true benefit.

option price of each person. The difficulty stems from the fact that being willing to make an aggregate payment of C is predicated upon achieving an efficient distribution of risk. Collecting payments corresponding to A and B, respectively, from the first and second people equates their marginal rates of substitution between "\$ if state 1" and "\$ if state 2" and is, therefore, consistent with efficiency. Collecting payments corresponding to D from each, on the other hand, does not equate marginal rates of substitution and is inconsistent with efficiency unless secondary markets are available in which the individuals can buy and sell contingent claims.

The case of independent risks poses similar problems. Looking back at Figure 4 we see that both expected willingness to pay, V, and expected surplus exceed option price. Should actual financing entail sure collections of either V or \$30 from each individual, everyone would be a loser in that situation as well unless a secondary market for insurance exists.

It is implicit in the original discussions of the "hypothetical compensation test" that complete markets exist for all goods. One need not be concerned with the allocational efficiency of taxation schemes in such circumstances since trade in the perfect secondary markets assures ultimate allocational efficiency. However appropriate, this "complete markets" assumption was for the riskless world of these original debates, it is generally conceded that many of the contingent claims markets required for allocational efficiency in a risky world do not exist.[5] It is crucial in such circumstances that either 1) the particular method of financing the project be evaluated with respect to its implications for the distribution of risk, or 2) the analysis be modified in such a way as to avoid dependence on nonexisting markets. For these reasons option price may be regarded as a "second best" measure of benefit appropriate to situations in which 1) actual financing involves sure collections from individuals,[6] and 2) secondary contingent claims markets are not available.

VI. Generalizations

The approach to the illustrative cases examined thus far may easily be generalized to situations involving an arbitrary number of periods and states. Consider a general situation involving S states and $Q+1$ periods and suppose that markets exist in which individuals can exchange current sure (time zero) dollars for M different types of assets. Ownership of one unit of the ith asset entails claims to receipts of

$$a^i_{sq}\begin{cases} s=1,\dots,S \\ q=1,\dots,Q \\ i=1,\dots,M \end{cases}$$

dollars at time q (the end of period q) if state s occurs. For notational convenience let current sure dollars be that asset indexed by zero. A portfolio, then, is an $M+1$ tuple, x, where the ith component x_i denotes the quantity of the ith asset, $i=0,\dots,M$. Holding the portfolio x thus entitles the owner to x_0 current sure dollars and claims paying

$$\sum_{i=1}^{M} x_i a^i_{sq}\begin{cases} s=1,\cdots,S \\ q=1,\dots,Q \end{cases}$$

dollars at time q if state s occurs. In vector

[5]There are at least two important reasons why many types of contingent claims markets do not exist. The first is moral hazard: a person buying claims contingent upon a particular state may have incentives to alter his behavior in a way that is adverse to the seller. Second, such markets require complicated and specialized contracts which may be costly both to write and to enforce.

[6]It might be thought that state-dependent collections represent an unrealistic method of financing projects. This is not necessarily true, however. In the case of the dam, for example, a combination of sure taxes and water charges might produce exactly the combination of contingent payments required for allocational efficiency. Sure taxes and visitor charges might similarly be used in the case of Yellowstone Park. In Figure 4 a sure tax of Ob in both states plus a visitor charge of Oa-Ob would produce exactly the desired result. In general, however, the same factors that prevent contingent claims markets from being privately organized would presumably inhibit the use of state-dependent collection schemes.

otation we have $c=Ax$ where

$$A\equiv\begin{bmatrix} 1 & 0 & 0 & \dots & 0 \\ 0 & a_{11}^1 & a_{11}^2 & \dots & a_{11}^M \\ 0 & a_{21}^1 & a_{21}^2 & \dots & a_{21}^M \\ \vdots & & & & \\ 0 & a_{SQ}^1 & a_{SQ}^2 & \dots & a_{SQ}^M \end{bmatrix}$$

and c is the $SQ+1$ vector of time-state dependent dollar claims associated with the portfolio x.

The utility function of the individual for consumption programs involving the $SQ+1$ possible types of time-state dependent claims $U(c)$ can be used to derive a utility function for portfolios by defining the utility of the portfolio to be equal to the utility of the associated vector of time-state dependent claims:[7] $u(x)\equiv U(Ax)$.

Similarly, if the list of goods is expanded to include the services to be derived from a proposed public project, then the notation $u(x,\delta)$ may be used to denote the utility of holding the portfolio x when the services are provided ($\delta=1$), or when the services are not provided ($\delta=0$). Supposing the individual to be endowed, following market trade, with the portfolio e the willingness-to-pay locus may be defined as consisting of those vectors γ which satisfy

$$\gamma=Ax;\quad u(e-x,1)=u(e,0)$$

By aggregating these loci across individuals in the manner suggested earlier, one obtains the aggregate willingness-to-pay locus. As before, the project is justifiable if the vector describing its resource costs lies below this aggregate surface. If, for example, all costs are to be incurred during the first period, then the relevant measure of benefit is the intersection of the aggregate surface with the current sure dollar axis.

Turning now to the matter of risk discounting we suppose first that it is meaningful to discuss a "riskless" interest rate, that is, we assume that there exist portfolios x^t which satisfy

$$\sum_i x_i^t a_{sq}^i=\begin{cases} 1 & s=1,\dots,S \\ & q=t \\ 0 & \text{otherwise} \end{cases}$$

for $t=1,\dots,Q$. (Ownership of x^t returns a sure dollar at time t and nothing at other times.) The existence of these riskless portfolios establishes the riskless discount rates applicable to returns at time t as

$$1/(1+r_t)\equiv px^t;\qquad t=1,\dots,Q$$

where $p\equiv(1,p_1,\dots,p_M)$ is the vector of time zero sure dollar prices of the assets. Now suppose another portfolio, x, offers risky returns at time T, that is,

$$\sum_i x_i a_{sq}^i=\begin{cases} z_s & s=1,\dots,S \\ & q=T \\ 0 & \text{otherwise} \end{cases}$$

The current market price of this risky portfolio must be px. This present value may equivalently be determined by noting that the ratio px/px^T represents the price of the risky portfolio in terms of time T sure dollars. This is the future, time T, value of the risky portfolio. To determine its present value notice that

$$px/px^T=px(1+r_T)$$

or that $$px=1/(1+r_T)\frac{px}{px^T}$$

Thus the present value of the risky portfolio is obtained by discounting its future value at the riskless rate. This is the direct result of

[7]Notice that this general formulation requires only that an individual have a utility function ranking alternative consumption programs. This is less restrictive than the von Neuman-Morgenstern formulation and compatible with other approaches, for example, the certain equivalence formulation of Handa (1977).

the existence of markets which afford opportunities for riskless investment.[8]

It should be noticed that this analysis supposes only that free competitive exchange is possible in the existing markets for assets. Although this is not equivalent to assuming the existence of complete contingent claims markets, it does include the case of complete markets as a possible special case. To see this notice first that the ability to buy and sell assets at prices $p=(1, p_1, \ldots, p_M)$ implies that an individual endowed with the portfolio e faces the "portfolio" budget constraint $px=pe$. Suppose now that the rank of A is equal to $SQ+1$, that is, there are as many linearly independent assets as there are types of contingent dollar claims. Then we may write $x=A^{-1}c$ and the portfolio budget constraint is equivalent to the "contingent claim" budget constraint given by $Pc=PE$ where $E\equiv Ae$ and $P\equiv pA^{-1}$. Here the ability to buy and sell assets at prices p is equivalent to the ability to buy and sell contingent claims at prices P. This situation is therefore equivalent to one in which complete markets exist for trade in contingent claims. In general, however, the rank of A may be less than $SQ+1$ in which case existing markets for assets do not provide opportunities for exchange of risk equivalent to those which would be afforded by a complete set of contingent claims markets.[9]

[8]The matter of discounting for risk may be clarified by a complete market example. Suppose there are S states with π_s denoting the objective probability of state s. Complete contingent claims markets exist with p_s the current price of a claim to one dollar in period two contingent upon the occurrence of s. The riskless discount rate is then $1/(1+r)\equiv\Sigma_s p_s$. Suppose now that ownership of an asset a entails claims to a_s dollars in period two if state s occurs, $s=1,\ldots,S$. The current market price of this asset must be $V=\Sigma_s p_s a_s$. This market value may also be calculated by determining the value of the asset in period-two sure dollars $\Sigma_s(p_s/\Sigma_j p_j)a_s$ and then discounting at the riskless rate

$$V=1/(1+r)\sum_s\left(p_s/\sum_j p_j\right)a_s$$

$$=\left(\sum p_j\right)\sum_s\left(p_s/\sum_j p_j\right)a_s=\sum_s p_s a_s$$

Now if one wished to discount the expected value of period two claims rather than their true second-period market value then one would require the risky discount rate corresponding to

$$1/(1+\rho)\sum_s \pi_s a_s=\sum_s p_s a_s=V$$

If market prices were proportional to probabilities, $\pi_i/\pi_j=p_i/p_j$ for all i, j, then $\pi_s=p_s/\Sigma_j p_j$ and $\rho=r$. In general, however, market prices are not proportional to probabilities and $\rho\neq r$. In such circumstances the use of ρ represents nothing more than a correction factor for having used probabilities rather than prices to measure the future value of receipts.

[9]For a general discussion of the relationship of the rank of the assets matrix to the opportunities for achieving efficient distributions of risk, see Steven Ross.

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The Optimal Tariff in the Antebellum United States

By JOHN A. JAMES*

Virtually from its founding the United States has not followed a free-trade policy. Tariffs were the principal source of federal revenue in the nineteenth century and protection of domestic industries was a significant factor as well from the first tariff act of 1789 onward (see Frank Taussig, pp. 14–15). One of the more interesting (and controversial, at least in the antebellum period) questions in American economic history as well as in international trade and development is what the effects of such a protective policy in fact were. It is well known that a country with monopoly power in international trade can improve its lot over the free-trade equilibrium. Up to some point by increasing its tariff, it should be able by improving its terms of trade also to increase national welfare. The antebellum United States may well have had such power due to its position as the major world supplier of raw cotton. In the period between 1840 and 1860, the United States produced almost two-thirds of world cotton output, while the United Kingdom, the major customer of new cotton, purchased 80 percent of its cotton imports from the United States (see S. Bruchey, pp. 9–10). Did the United States exploit its monopoly power to full advantage through its tariff policy? In other words, what was the optimum tariff,[1] the tariff rate which maximized national welfare, in the antebellum United States and how did it compare with actual tariff levels?

In spite of the prominent position of the optimum tariff in trade and development literature, almost no work has been done in calculating actual levels of optimum tariffs. Simulated values have been computed for varying parameters (L. B. Yeager; Johnson, 1968; L. Thurow and H. White; E. Tower, A. Sheer, and H. Baas), but only D. McCloskey has attempted to measure an optimum tariff using empirical data, assuming constant elasticities (for nineteenth-century Britain). In this paper, the optimal tariff will be computed in a less restrictive framework for the United States in 1859. A general equilibrium approach is necessary to capture the complex interactions between production distortions, changes in factor incomes, and consumption patterns due to the tariff. The Scarf algorithm[2] will be used to solve for the equilibrium price vector in a general equilibrium model of the 1859 *U.S.* economy.[3] Such an approach allows a much more flexible formulation of the problem. Equilibrium prices may be solved for explicitly in an n-sector competitive economy, specifying only the initial endowments, production or supply functions, and utility or demand functions. Constant elasticity demand and supply curves, for example, need not be resorted to, in order to make the problem manageable. The *U.S.* equilibrium will be computed under a range of tariff rates, and then the level of national welfare associated with each of these equilibria will be compared to determine the optimum tariff. Section I will describe the model, while Section II will evaluate the optimum tariff.

I

In order to be able to assess the impact of varying tariff rates, the model includes two countries—the United States and the Rest of the World (*ROW*), which is assumed to produce only exportables. There are fourteen

*University of Virginia. I am particularly indebted to Robert Flood and John Whalley for comments, and to Gary Fournier for research assistance. The usual responsibility for errors, nevertheless, rests with me.

[1]For discussions of the optimum tariff, see J. Van de Graaff or Harry Johnson (1951).

[2]Descriptions and applications of the Scarf algorithm may be found in a number of articles. See, for example, Scarf (1969, 1973); Shoven and Whalley (1972); Shoven; Whalley.

[3]To be precise, the algorithm used in this paper is modified somewhat to allow for the existence of tariffs following Shoven and Whalley (1974).

TABLE 1—PARAMETER SPECIFICATIONS FOR THE MODEL

	Production				
	Labor Coefficient	Capital Coefficient	Land Coefficient	Slave Coefficient	Elasticity of Substitution
United States:					
Manufacturing	.44	.56			.45
Cotton Textiles	.41	.59			.86
Labor-Intensive Services	.80	.20			.10
Capital-Intensive Services	.10	.90			.10
Foodstuffs (free labor)	.24	.32	.44		1.00
Foodstuffs (slave labor)		.25	.25	.50	1.00
Cotton		.17	.25	.58	1.00
ROW:					
Manufacturing	.35	.65			.45
Cotton Textiles	.30	.70			.86

	Consumption	
	Intergroup Substitution Elasticity σ	Intragroup Substitution Elasticity S
United States:		
Slaves	.1	–
Laborers	.6	2.0
Capitalists	.8	2.0
Landowners and Slaveholders	.8	2.0
ROW:		
Laborers and Capitalists	.75	

goods: eight final goods and six inputs. The final goods include two import-competing goods, domestic manufactures and domestic cotton textiles; two imports, *ROW* manufactures and *ROW* cotton textiles; two exports, foodstuffs and cotton; and two nontraded goods, labor-intensive and capital-intensive services. There are six factors of production: labor; capital; land; slaves; *ROW* labor; and *ROW* capital. It is assumed that the economy has zero endowments of all final goods initially and, of course, positive endowments of factors of production. Factors are measured in physical units which generate one dollar of factor income in the initial 1859 equilibrium. Similarly, output units represent one dollar of output in the initial equilibrium. Perfect competition and constant returns to scale are assumed. The sectors of the model will be described briefly here, however more detail is available in my earlier article.

Production in the nonagricultural sectors of the 1859 *U.S.* economy is assumed to have followed a standard *CES* production function, such as in equation (1),

$$(1) \qquad Q_i = \gamma_i\left[\alpha_i L_i^{-\rho_i} + \beta_i K_i^{-\rho_i}\right]^{-1/\rho_i}$$

where L_i and K_i represent labor and capital inputs, respectively, in the ith sector; Q_i is sector value-added; α_i and β_i are factor-input weights; ρ_i is a measure of the ease of factor substitution; and γ_i is a normalizing constant. The industrial sector is here divided into cotton textiles and other manufactures. Textiles are considered a separate sector because thereby we are able to incorporate the fact that the major *U.S.* export, raw cotton, is actually an intermediate good explicitly into the model. The parameters for the manufactures and textiles production functions, which are reported in Table 1, were estimated from cross-section regressions using the cost-minimizing form of the *CES*

on data reported in the 1860 Census of Manufactures.[4]

Production in the model is described by an activity analysis matrix

$$(2)\quad A=\begin{bmatrix} -1 & \cdots & 0 & a_{1,n+1} & \cdots & a_{1,m+n} \\ 0 & & 0 & a_{2,n+1} & & a_{2,m+n} \\ \cdot & & \cdot & \cdot & & \cdot \\ \cdot & & \cdot & \cdot & & \cdot \\ 0 & \cdots & -1 & a_{n,n+1} & \cdots & a_{n,m+n} \end{bmatrix}$$

where there are n goods and m activities. Each column is a feasible activity (or production technique) which may be operated at any nonnegative level. The first n columns allow for the possibility of free disposal, while the remaining m columns may be used to represent the production process in each sector. Equation (1), for example, is evaluated for various combinations of L_i and K_i, so that a set of columns can approximate a unit isoquant.

The service sector constituted about 40 percent of total output in the antebellum period (see Gallman and Weiss, p. 291). It must be explicitly included in the model, but little data on it are available. As a result, the production functions must be imposed. The sector is divided into two components—labor-intensive and capital-intensive services.[5] A *CES* production function as in equation (1) is assumed with the parameters listed in Table 1. A low substitution elasticity is postulated because it seems unlikely that there was much possibility of factor substitution in these industries at the time. The greater share of factor income goes to the factor used intensively in each sector. The service sectors play the role of nontraded goods in the model.

Agricultural production functions are assumed to be Cobb-Douglas, as in

$$(3)\qquad Q_i=\gamma_i L_i^{\alpha_i} K_i^{\beta_i} T_i^{\delta_i}$$

where α_i, β_i, and δ_i are the factor shares of labor, capital, and land, respectively. Such a specification is consistent with both contemporary evidence and that for the postbellum South (see Griliches; DeCanio). The production function for foodstuffs produced by free labor was estimated from nonslave state data from the 1860 Census of Agriculture. The estimated parameters are reported in Table 1.

Slave plantations were more specialized in cotton production than southern free farms and the proportion of cotton in total output varied with the size of the farm (see Wright, 1975, p. 445). Therefore, let us assume that all cotton is produced by slave labor. The factor shares for cotton production are taken from the estimates of Fogel and Engerman (1974, pp. 132–33).[6] An alternative use of slaves, the production of foodstuffs, is also introduced into the activity matrix to make the model more flexible. Since cotton was relatively labor intensive, slave production of foodstuffs is assumed to have been less labor intensive than cotton production, but still more so than foodstuffs production by free labor. Self-sufficient foodstuffs production of plantations (see Hutchinson and Williamson) is netted out, so in the initial equilibrium all slave labor was engaged in cotton production.

Since the United Kingdom was the principal trader with the United States, the *ROW* sector is taken to resemble the United Kingdom. For example, *ROW* factor endowments are chosen to be of the same magnitude in relation to those in the United States as

[4]This specification of antebellum industry is consistent with the existing literature. More detailed studies have supported the constant returns to scale characterization in the iron industry (Peter Temin, 1964; Robert Fogel and Stanley Engerman, 1969) and in cotton textiles (Paul David, 1970), while David and Moses Abramovitz have also estimated the elasticity of substitution for the nineteenth-century United States to be less than one.

[5]Labor-intensive services include finance, professional services, personal services, government, education, and independent hand trades. Capital-intensive services are transportation, public utilities and shelter (Gallman and Weiss, pp. 305–29).

[6]Constant returns in cotton production is assumed also. Wright (1975, p. 445) finds no scale economies at the farm level, in contrast with Fogel and Engerman (1974), whose findings are nevertheless consistent with constant returns at the industry level.

those in the United Kingdom were.[7] Following Temin (1973, pp. 165–79), the *ROW* is assumed to have been capital-abundant relative to the United States. *ROW* production is limited to manufactured goods and cotton textiles, which together constituted over 80 percent of dutiable imports in the 1859 United States.[8] Both industries are assumed to have had *CES* production functions such as equation (1) and the same technology as domestic industries. Tariffs are imposed equally on both imported goods in tracing the optimal tariff.[9] For simplicity, let us assume that all tariff revenues are redistributed among consumers in proportion to their share of national income, so that the government sector is always in balance with receipts equaling disbursements.

On the demand side, individuals are grouped by factor incomes, so that there are four domestic consumers-laborers, capitalists, land and slave owners, and slaves—and two foreign consumers—*ROW* laborers and *ROW* capitalists. Income for each group consists of factor income plus redistributed tariff revenues. Each consumer is taken to derive his demands from maximizing a utility function subject to a budget constraint to ensure that the budget is exhausted. A desirable form of the utility function would allow for some adaptability in consumer choice. In particular, expenditure shares should be able to change in response to changes in relative prices, and also rates of substitution in consumption should differ between different pairs of goods. The elasticity of substitution in *U.S.* consumption between domestic and *ROW* manufactures, for instance, should be quite different from that between manufactures and foodstuffs. Such properties may be found in the *S*-branch utility function of Brown and Heien, a generalization of Sato's two-level *CES* production function,

$$(4)\quad U=\left\{\sum_{i=1}^{N}\alpha_i^{1+\rho}\left[\sum_{j=1}^{n_i}\beta_{ij}^{1+\rho}Q_{ij}^{-\rho}\right]^{\rho/\rho_i}\right\}^{-1/\rho}$$

where there are N major groups of commodities and within each major grouping there are n_i individual goods. Also, $\rho_i=(1/S_i)-1$ and $\rho=(1/\sigma)-1$, where S_i and σ are the intragroup substitution elasticity within the ith group and the intergroup substitution elasticity, respectively. The utility function is on two levels. The consumer on the first level chooses between services and manufactures, and then at the second chooses between domestic and *ROW* manufactures.

Lack of sufficient expenditure data prevents direct estimation of the utility function parameters of consumer groups, so they must be imposed. All consumers are assumed to have inelastic elasticities of substitution, the rate rising with the income level of the group, as also shown in Table 1. Thus, slaves have the lowest substitution elasticity,[10] then laborers, then capitalists and land and slave owners. The expenditure share on manufactures and textiles are divided into domestic and imported goods. As suggested in footnote 8, foreign and domestic goods were reasonable but not perfect substitutes, so we assume the intragroup substitution elasticity between them to be 2.0. Furthermore, in the initial equilibrium, it is assumed that each consumer's expenditure share on a particular good equals the proportion of expenditures on that good in total consumption expenditures. Normalizing parameters therefore are chosen to generate in the initial equilibrium a price vector with all producer prices equal

[7]By thus limiting the *ROW* sector, we may be overestimating the effects of *U.S.* tariff changes on *ROW* prices and output. See my earlier article, pp. 246–53.

[8]Foreign and domestic manufactures and textiles are taken in the model to be separate commodities because difficulties arise in a competitive general equilibrium model in explaining a trade flow in both directions in a homogeneous commodity. Such nonhomogeneity, however, seems to have been the case in a number of import goods. For example, British textile imports were primarily more expensive items in contrast to domestic production (see Zevin, p. 128).

[9]Textiles constituted such a small proportion of total imports that little is lost by assuming a uniform tariff rate. The effects of the *ceteris paribus* removal of the tariff on textiles were very small as compared with changes in the manufactured goods tariff (see my earlier article, p. 250).

[10]Slave's consumption is taken to be at the subsistence level with slave earnings above that accruing to the slave owners.

TABLE 2—MODEL OF THE *U.S.* ECONOMY IN 1859
($ million)

Gross National Product			
Value-Added		Factor Income	
Manufactures	814.1	Labor	1628.90
Cotton Textiles	58.4	Capital	1730.63
Foodstuffs	1246.5	Land	612.84
Cotton	248.5	Slaves	144.13
Labor-Intensive Services	1095.0		
Capital-Intensive Services	654.0		
Total	4116.5	Total	4116.50

Balance of Trade			
Exports		Imports	
Foodstuffs	85.0	Manufactures	244.2
Cotton	175.2	Cotton Textiles	16.0
Total	260.2	Total	260.2

Tariff revenues 52.68

to unity and sector totals of *GNP* equal to those of the 1859 United States.

ROW consumers are assumed to have *CES* utility functions, to which the *S*-branch form reduces in the absence of a difference between the intragroup and intergroup substitution elasticities. They purchase *ROW* manufactures, *ROW* textiles, and *U.S.* foodstuffs. Cotton exported by the United States is used in the production of *ROW* textiles.[11]

Table 2 presents the initial equilibrium of the model. Gallman (1966) estimates the 1859 *GNP* in current prices at $4,170 million, while in the initial equilibrium in the general equilibrium model it is $4,116.5 million.[12] The specification of the model in its initial equilibrium, therefore, is quite close to the structure of the 1859 *U.S.* economy.

[11]In 1859, cotton accounted for 58 percent of the total value of commodity exports, while agricultural products and raw materials comprised 88 percent of total commodity exports (U.S. Secretary of the Treasury, pp. 24–39; 396–401). As a result, there are two export goods in the model, cotton and foodstuffs.

[12]The discrepancy is accounted for primarily by omissions in the general equilibrium model to make it more manageable. For example, the mining sector, amounting to $34 million, is suppressed (Gallman, 1960, p. 54); flour and meal was taken out of the manufacturing sector since it was not an import-competing good.

II

In order to estimate the optimum tariff for the 1859 United States, a series of counterfactual equilibria was computed under varying tariff rates.[13] As the tariff rate rises, relative price movements in the model appear to be quite reasonable (i.e., in line with what one would expect from international trade theory). The prices of import-competing goods, domestic manufactures and cotton textiles, rise relative to the producer (net of tariff) prices of imports. Export goods prices fall relative to nontraded goods prices, while the prices of import-competing goods rise relatively. Furthermore, as the tariff increases, the *U.S.* terms of trade improves continuously. Table 3 presents a Laspeyres index of *U.S.* terms of trade as computed for selected tariff rates.

The profile of real income in the 1859 United States as a function of the *U.S.* tariff rate, measured by a Laspeyres quantity index initialized at the free-trade equilibrium, is presented in Figure 1.[14] First, it may be

[13]As a test for uniqueness of the equilibria, the algorithm was started from different points on the simplex. In all the cases that were tried, the algorithm converged to the same price vector for a given tariff rate.

[14]A Paasche index also followed the pattern of Figure 1 very closely. Since there is no ambiguity about the

TABLE 3—CHANGES IN THE *U.S.* TERMS OF TRADE

Tariff Rate[a]	Terms of Trade
0	1.0000
5	1.0863
10	1.1272
15	1.1817
20	1.2014
25	1.2312
30	1.3053
35	1.3212
40	1.3561
50	1.4407
60	1.5629
70	1.6292
80	1.6380
100	2.0391

[a]Shown in percent.

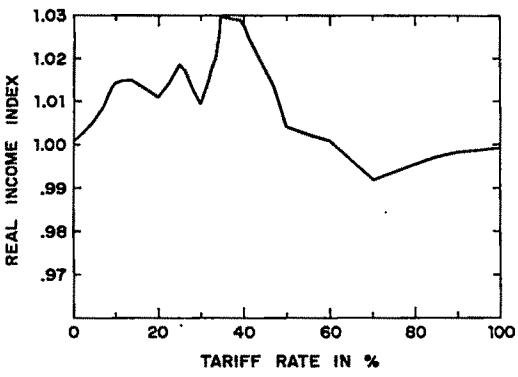

FIGURE 1. *U.S.* REAL INCOME INDEX AS A FUNCTION OF THE TARIFF RATE, 1859

noted that in contrast to the textbook depiction of the optimum tariff (see Bhagwati and Kemp; Caves and Jones), the curve in Figure 1 is not unimodal, rising from free trade to the optimum level and then declining until the range of prohibitive tariff rates is reached. Instead, the index is multimodal, with a brief rise in real income at low tariff rates, a small peak at rates around 25 percent, and then a larger peak at rates around 35 to 40 percent. As might be suspected, real

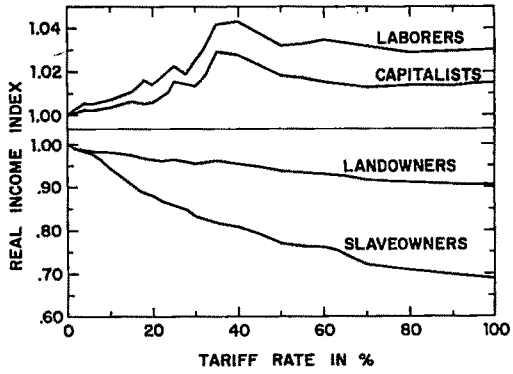

FIGURE 2. DOMESTIC MANUFACTURING OUTPUT AS A FUNCTION OF THE TARIFF RATE, 1859

income falls off at higher tariff rates, here starting at about 40 percent. The optimum tariff for the United States in 1859 therefore seems to have been in the range of 35 to 40 percent.[15]

This multimodal configuration makes it quite treacherous to draw inferences about tariff policy in the large from considering the effects of small, local changes in tariff rates. Such a finding is consistent with Edward Tower's warning that it is difficult to rule out the possibility of multiple optima in tariff models. As a result, even quite simple models may produce a multimodal utility profile, so the optimum tariff calculator should be wary. Figure 2 shows that this configuration is somewhat reflected in *U.S.* production of the import-competing good, manufactures, as the tariff rate varies, even though in general output of domestic manufactures increases with the tariff rate. The change in manufacturing output caused by increases in the tariff is rather small because, even though the price of *ROW* manufactures is rising relative to that of domestic manufactures, manufac-

direction and virtually none about the levels of real income changes, only the Laspeyres index is depicted in the interests of diagrammatical simplicity. Moreover, a simple social welfare function, the sum of all consumer utilities, follows the same pattern.

[15]Such a real income profile however is ultimately not entirely legitimate, because government revenues are changing along with the tariff rate, which is the only source of government receipts. If the government had had some minimum level of expenditures that had to be met, then at low tariff rates new taxes would have had to have been imposed, in turn creating distortions of their own. This complication is ignored in the analysis here which assumes that the government is purely a redistributive agent.

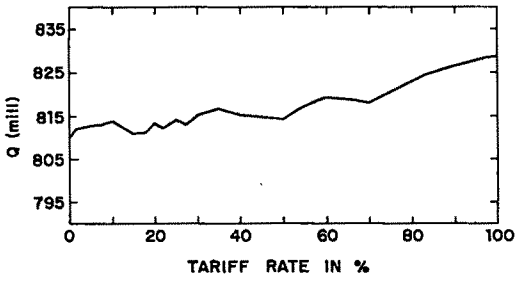

FIGURE 3. CONSUMER REAL INCOME INDEXES AS A FUNCTION OF THE TARIFF RATE, 1859

tured goods prices in general are rising relative to prices of other goods, inducing consumers to substitute away from them.

The level of real income at the optimum tariff is something less than 3 percent higher than that at the free-trade equilibrium. Such a difference is fairly substantial in relation to the size of the international sector in the 1859 United States. In the initial equilibrium in Table 2, trade flows amount to only 6.3 percent of *GNP*. Indeed, it is also a sizable figure in comparison with estimates in the literature of the magnitudes of tax-induced distortions. For example, John Shoven's estimate of the static efficiency cost of taxation on capital income for the 1953–59 period in a 12-sector general equilibrium model amounted to only .5 percent of *GNP* (p. 1281).

The imposition of tariffs may also have had substantial redistributional effects among the factors of production as well (Thurow and White; James, pp. 247–48). In Figure 3 we see a consumption-based Laspeyres real income index as a function of the tariff rate for each domestic factor of production. The impact of the tariff on individual factors real incomes varies significantly from factor to factor. First of all, it is rather interesting that the real income profiles of laborers and capitalists move so closely together. This pattern also roughly parallels the changes in aggregate real income in Figure 1. All three show a local maximum at a 25 percent tariff rate and a global maximum at 35 to 40 percent. The principal beneficiary from an optimum tariff policy apparently would have been labor. The real income of laborers would have been over 4 percent higher at the optimum tariff as compared with the free-trade equilibrium. Even at quite high tariff rates real income gains to laborers remain quite significant. Capitalists also would have benefited by an optimum tariff policy, although to a lesser extent, real returns to capital being slightly less than 3 percent higher at the tariff optimum than at the free-trade equilibrium.

In contrast, the real income levels associated with the factors of production used intensively in export-good production, land, and slaves, decline virtually continuously as the tariff rate is increased from the free-trade level. The decline in slaveowners' real income is the most pronounced, with a fall of almost 20 percent between the free-trade and the optimum-tariff level. Landowners' real income levels, on the other hand, do turn upward slightly between tariffs of 30 to 35 percent, but still decline about 5 percent from the free-trade to the optimum-tariff level. Clearly, laborers and capitalists would have been the gainers of an optimum tariff policy in the antebellum United States, while landowners and slaveowners would have been injured.

The sensitivity of complex general equilibrium models to exact parameter specification is widely known. To examine the influence of specification on our calculations of the optimum tariff, let us assume alternatively that domestic and imported manufactures are quite close substitutes in *U.S.* consumption, taking the intragroup substitution elasticity S to be equal to 5.0 rather than 2.0. With the increased substitution elasticity, the small local maximum at low tariff rates when $S=2.0$ becomes the global maximum. The local maximum at a tariff rate around 25 percent remains, but utility and real income levels fall off markedly at higher tariff rates. The optimum tariff falls from about 35 to 5 percent. The increase in real income at the optimum tariff level compared with free trade is about 2 percent, a smaller figure than the slightly less than 3 percent change when $S=2.0$.

In order to compare our calculation of the optimum tariff with antebellum tariff history, consider Table 4. With an average tariff

TABLE 4—AVERAGE *U.S.* TARIFF RATES (Shown in Percent)

Year	Duties/ Total Imports	Duties/ Dutiable Imports
1821	43.2	45.0
1825	47.7	50.5
1830	57.3	61.7
1835	21.2	40.4
1840	17.6	34.4
1845	29.3	34.5
1850	24.5	27.1
1855	23.4	26.8
1860	15.7	19.7

Source: *Historical Statistics*, p. 888.

rate on dutiable items of about 20 percent, the United States tariff rate in 1859 was clearly below the optimum level. In fact, the real income level associated with the actual 1859 rate appears to have been around a local minimum. A move to the optimum tariff level in 1859 would have increased *U.S.* real income by about 1.75 percent, or $72 million in the model.

Over the antebellum period, the share of the United States in world cotton production increased steadily, from 28.6 percent in 1820 to 66.0 percent in 1860. (see Bruchey, p. 7) In the face of this rising world market share, the demand for *U.S.* cotton might have been becoming increasingly inelastic over the antebellum period.[16] If so, the *U.S.* optimum tariff level would have been rising over time, *ceteris paribus*. However, we observe the opposite pattern in *U.S.* tariff rates in Table 4. Tariff rates generally declined from the high of the Tariff of 1828 to 1860. The rates of Tariff Act of 1824 and 1828 were above the 1859 optimum level, and thus a fortiori probably above the optimum level of the time. A reduction in tariff rates was called for to maximize national welfare, but ironically that reduction continued over the 1840's and 1850's as the monopoly power of the United States in international trade may have been growing. As a result, by the eve of the Civil War the prevailing tariff rate was below the optimum.

[16]This argument contrasts with Wright's estimate of a unitary elasticity of demand for *U.S.* cotton in the antebellum period (1978, p. 92).

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A Theory and Test of Credit Rationing: Some Further Results

By ENRIQUE R. ARZAC, ROBERT A. SCHWARTZ, AND DAVID K. WHITCOMB*

In his extension of Dwight Jaffee and Franco Modigliani's theory of credit rationing, Vernon Smith derived an important proposition about lending behavior under a fixed interest rate. Assuming risk indifference, he proved that the optimal size of the loan is proportional to the borrower's equity. This note considers whether Smith's proposition can be extended to risk-averse behavior. We show that Smith's proposition is nonextendable in a strict sense; that is, under lender risk aversion, the lender's optimal loan offer is inelastic with respect to the borrower's equity. However, in equilibrium if the interest rate is fixed but there is competition in leverage terms, the market will establish a fixed leverage ratio for all loans whose proceeds are invested in the same risk asset (whether lenders are risk neutral or risk averse).

I. Leverage Terms under Risk Aversion

Consider a lender who allocates his capital K between an investment in a riskless asset with rate of return $s-1$ and a loan of an amount L to a borrower at the fixed contractual interest rate $r-1(r>s)$. The borrower invests L plus equity C in a risk asset yielding the random rate of return $R-1$. The investment $C+L$ is pledged as collateral but the borrower enjoys limited liability in that any other assets he happens to own are not subject to the lender's claim.

Expressing the borrower's leverage ratio as $V=L/(C+L)$, the random return on the loan is

$$\tilde{r}=\begin{cases} r & \text{if } R\geqslant R^*(=rV) \\ R/V & \text{if } R<R^* \end{cases}$$

where R^* is the default return on the risk asset (any return below R^* is insufficient to repay the loan in full).

The lender's wealth is $W(R)=L\tilde{r}+(K-L)s$. Assuming the lender has a differentiable subjective probability distribution of returns on the risk asset, $F(R)$, with density $f(R)$ and $F(0)=0$, and a twice differentiable utility function $U(W)$, his expected utility is

(1)

$$E(U)=\int_0^{R^*} U[(C+L)R+(K-L)s]\,dF(R) + U[Lr+(K-L)s][1-F(R^*)]$$

We now prove:

PROPOSITION 1. *At the lender's optimum, when the contractual interest rate is fixed and* $C>0$:

(a) $dV/dC<0$ *under risk aversion*;

(b) $dV/dC=0$ *under risk neutrality.*

PROOF:

(a): Differentiating (1) with respect to L yields the following necessary condition for optimal lending:

(2)

$$\int_0^{R^*} U'[(C+L)R+(K-L)s](R-s)\,dF(R) + U'[Lr+(K-L)s](r-s)[1-F(R^*)]=0$$

Differentiating (2) totally with respect to C yields

$$(3)\quad \int_0^{R^*} U''[W(R)](R-s)^2\frac{dL}{dC}dF(R) + U''[W(R^*)](r-s)^2\frac{dL}{dC}[1-F(R^*)] + U'[W(R^*)](R^*-r)f(R^*)r\frac{dV}{dC}=0$$

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Under risk aversion, and since $R^*<r$, (3) will be satisfied iff $sgn(dL/dC)=-sgn(dV/dC)$. Then, since

$$\frac{dV}{dC}=\frac{V^2}{L}\left(\frac{C}{L}\frac{dL}{dC}-1\right) \tag{4}$$

dV/dC cannot be >0 for $dL/dC<0$. Hence, (3) will be satisfied iff $dL/dC>0$ and $dV/dC<0$.[1]

(b): For $U''(W)=0$, (3) immediately gives $dV/dC=0$.

Remarks:

1) It is straightforward to verify that Proposition 1 also holds when the alternative investment available to the lender is risky.

(2) In contrast to Smith's result under risk neutrality, Proposition 1 and equation (4) show that, under risk aversion, the elasticity of the lender's optimal loan offer with respect to the borrower's equity is less than 1. Intuitively this is because an increase in C with a proportional increase in L (i.e., V constant) causes the lender to hold a riskier portfolio than he did before. With r fixed, the lender must be compensated by a decrease in leverage.

II. Leverage Terms when Costless Arbitrage by an Intermediary is Possible

If the interest rate is fixed (for example, by regulatory fiat) one would expect market competition to focus on leverage terms. In this section we allow for the possibility of arbitrage in leverage terms by an intermediary and prove the following:

PROPOSITION 2. *In a credit market operating under a fixed interest rate but otherwise unrestrained competition, a differing leverage ratio across loans is incompatible with equilibrium in the sense that it would permit the realization of arbitrage profits by an intermediary.*

PROOF:

Let the leverage ratio vary across loans, with a fixed interest rate and one risk asset that provides collateral (either directly or indirectly). Consider an intermediary who searches borrowers and lenders for leverage discrepancies. Let the intermediary lend some low V borrower L_B against collateral C_B+L_B and borrow from some high V lender $L_I=L_B$ against collateral of C_I+L_I. Then, with $V_I>V_B$ which implies $C_I<C_B$, the intermediary need pledge no capital of his own, and is able to retain part of B's capital in the event of default. With this transaction the intermediary obtains an absolutely preferred (i.e., stochastically dominating) change in the distribution of his final wealth as shown in Table 1.[2] The second inequality in the last column of Table 1 follows from $L_B=L_I$ and $R<rV_I=rL_I/(C_I+L_I)$.

Arbitrage will produce constant leverage across all loans backed up by the same kind of risk asset since (by the proof of Proposition 1), in order to obtain additional loans, intermediaries will have to offer lower leverage. To make more loans, they will have to accept higher leverage. Since the expected utility of the borrower increases with his leverage,[3] the intermediary can increase the size of his loan portfolio by accepting higher leverage terms (attracting borrowers who would otherwise need to pledge more of their equity as collateral to other lenders).

[1]Azzi and Cox show that $dL/dC>0$ under risk aversion, but $dL/dC>0$ does not by itself imply $dV/dC<0$ without (3) as we see from (4).

[2]Note that this proof assumes $L_B=L_I$. The additional assumption that the intermediary can combine and/or split loans would allow one to extend the proof to the case of different loan sizes.

[3]Suppose the borrower invests the amount K_B+L-M in the risk asset, where K_B is his initial capital and M is his investment in the riskless asset. Since, for a given leverage ratio $V, C=L(1-V)/V$, the borrower's expected utility is

$$E(U_B)=\int_0^{R^*}U[(K_B-M-L(1-V))R+Ms]\,dF(R)$$
$$+\int_{R^*}^{\infty}U[(K_B+L-M)R-Lr+Ms]\,dF(R)$$

we immediately have that $\partial E(U_B)/\partial V>0$.

TABLE 1

R range	Loans Defaulted	Final Wealth Generated by Intermediation
$[0, rV_B)$	L_I, L_B	$(C_B - C_I)R > 0$
$[rV_B, rV_I)$	L_I	$L_B r - (C_I + L_I)R > 0$
$[rV_I, \infty)$	none	0

ratio will vary with the riskiness of the asset backing up the loan and variations in leverage will then substitute for variations in the interest rate. However, it can readily be shown along the lines of Smith that competition in leverage terms would be insufficient to correct the inefficient allocation of claims produced by the market when the interest rate is fixed.[4]

[4]When interest rates are free to vary, our earlier article shows that competitive equilibrium implies the existence of a positive leverage structure of interest rates that is Pareto efficient.

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The Welfare Effects of Market Shapes in the Löschian Location Model: Squares vs. Hexagons

By WILLIAM L. HOLAHAN AND RICHARD E. SCHULER*

Under what set of conditions is the location theorist's ideal, hexagonal-shaped market areas for spatially dispersed firms, likely to be observed in a nonplanned economy? Curtis Eaton and Richard G. Lipsey (E-L) recently explored this problem for a competitive economy and concluded that regular, hexagonal market areas can emerge and persist only if the society begins with triangular or hexagonal market configurations, but entry can destroy these regular lattices. They also show through their computer simulations that in the Löschian uniform plane, squares beget squares, rectangles beget rectangles, and that geometric configurations with unequal sides can persist. Such persistence of other shapes raises questions regarding the welfare superiority of hexagonal markets. Hexagons are demonstrably superior to other market shapes if they all have the same market area (see Martin Beckmann). However, if population growth or changing technology leads to sequential entry of new firms over time it will be shown that the sequence of entry is different for different spatial configurations of markets, and therefore the market radius will not be the same for different market shapes. In that case, will an area be better served by a lattice of hexagons or squares if the squares are smaller?

We demonstrate in Section I how market shape persistence can be obtained without computer simulation using most of the behavioral assumptions customarily used in location theory (see Edwin Mills and Michael Lav or Beckmann as examples). Both Eaton and Lipsey and we depart from traditional theory in assuming that existing firms will not relocate unless their profits will be strictly greater at the new location. Traditional theory places existing firms on frictionless roller skates so they will always relocate to accomodate a new entrant, even if they gain no advantage in doing so. Most of our other behavioral assumptions are closely aligned with traditional theory, as summarized in Table 1, and in this respect our analysis differs from Eaton and Lipsey's. The most significant difference is in the conjecture that potential entrants form about the likelihood that other new firms will enter the market. Eaton and Lipsey examine the most profitable entry point for a single new entrant only, regardless of the feasibility of profitable entry by other new firms at the same time. By comparison, we presume that the new entrant will predicate its location and pricing decision on the presumption that others will follow suit, if profitable. Our entrant's pre-entry expectations are consistent with post-entry profits. So, Eaton and Lipsey describe a myopic, firm by firm type of sequential entry; we describe a process where sequential waves of entry take place; traditional theory describes a continuous rearrangement process which leads to continuous entry.

For the purposes of this analysis the other differences in assumptions summarized in Table 1 are less important. However, we do note that the two, multiplicatively separable demand functions assumed by Eaton and Lipsey lead to pricing and market area decisions by producers which are completely independent. Thus E-L's simulations are, in effect, predicated upon assumptions by potential entrants that existing firms will neither relocate *nor change their price* in response to the new entry. The first assumption is explicit; the second is an implicit

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TABLE 1—A COMPARISON OF ASSUMPTIONS USED IN LOCATION THEORY ANALYSES

Topic	Eaton & Lipsey	Traditional Location Theory Analysis	Holahan & Schuler
1. Entry	Sequential (one at a time)	Simultaneous	Sequential Waves
2. Consumer Demand	$q=\bar{q}$ and $q=e^{-(p+r)}$ multiplicatively separable, no reservation price	A Wide Variety	$q=1-p-r$ not multiplicatively separable, contains a reservation price
3. Conditions for Relocation	$\pi_A > \pi_0$	$\pi_A \geqslant \pi_0$	$\pi_A > \pi_0$
4. Mobility Costs	Zero	Zero	Zero
5. Conjectural Assumptions Made by Entrant or Relocating Firm with Respect to			
a. Possibility of other entrants	No: Presumes no other entrants to other profitable areas.	Yes: Assumes as many as find it profitable will enter.	Yes: Assumes as many as find it profitable will enter.
b. Possibility of price response by other firms to my entry	No: Prices exogenously given, or irrelevant in the case of multiplicatively separable demand functions.	Yes: Assumes each will compute profit-maximizing price, given new sales boundary.	Yes: Assumes each will compute profit-maximizing price, given new sales boundary.
c. Own future relocation	Not anticipated	Not anticipated	Not anticipated

Note: Symbols are defined following equation (1). π_A = anticipated firm profits in new location; π_0 = firm profits in current location.

consequence of choosing multiplicatively separable demand equations. Furthermore, both demand equations used by E-L do not have a reservation price, and several of the market shapes we will generate, circles and rounded squares, would not appear without a reservation price. (In fact, under mill pricing, a single monopolistic producer could serve customers profitably at an infinite distance if there is no reservation price in their demand function.)

The models we develop in Section I facilitate the primary investigation of this paper, the welfare implications of two market shapes, squares versus hexagons, which are compared in Section II. We show that under competitive entry, square market shapes frequently lead to higher levels of consumer's surplus and total welfare than do hexagonal shapes (for similar states of production technology and customer density). But we also show that neither shape dominates the other, and which shape emerges hinges substantially on the "accident" of original settlement patterns. In short, while hexagonal market shapes lead to higher levels of welfare in a planned economy, square shapes may be preferred at times in a competitive environment where underlying population and technological changes are occurring.

I. Closed Form Equilibrium Solutions for Both Hexagonal and Square Market Configurations

Since we will shortly show that the initial configuration of firms dominates subsequent configurations (except for a triangular market area), it is interesting to backtrack to non-space-filling market areas in order to see how square or hexagonal market shapes might evolve. Figure 1 illustrates three possible non-space-filling configurations of monopolists. Non-space-filling monopoly will usually occur either when a new industry is emerging or when a new isolated region is being settled or developed. The analysis begins by reviewing the behavior of a single, non-space-filling monopolist.

A. *One Producer in von Thünen Space*

Consider one producer selling over an infinite plane with uniformly distributed identical customers. Then assuming linear

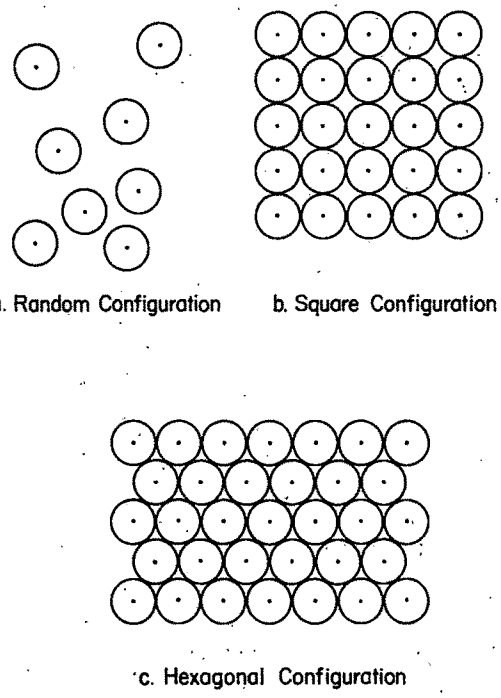

FIGURE 1. POSSIBLE CONFIGURATIONS OF PRODUCERS WHO ARE SPATIAL MONOPOLISTS

demand and cost functions, the spatial monopolist will maximize the following profit expression:

(1)

$$G_c=\int_0^{2\pi}\int_0^B v(P-m)(1-P-r)r\,dr\,d\phi-F$$

where G_c = total profit of spatial monopolist serving a circular area

$q=(1-P-r)$ = demand per customer with normalized dimensions[1] for P, r, v, and m

P = mill price

r = distance from customer to firm

ϕ = angular measure in the plane

v = population density = customer per unit area

$C=mQ+F$ is the cost function giving rise to decreasing average cost

where m = marginal cost (assumed = 0 for computational simplicity)

F = fixed cost

Q = total output of the firm

B = radius of circular market.

Since transport costs are assumed to be identical in all directions the firm will be at the center of a circular market area.

Maximization with respect to P and B yields the triplet $(P, B, G_c)=(1/4,\ 3/4,\ .1104v-F)$.[2] Hence the crucial ratio of fixed costs to customer density of $F/v\leqslant .1104$ is required in order for the firm to stay in business. If this ratio is not exceeded, additional producers who are assumed to be costlessly mobile will enter the von Thünen plane.

B. *Many Producers in von Thünen Space*

As additional firms enter the plane, it is difficult to imagine how one particular initial geometric configuration might dominate another. It is just as likely that firms will try to stay far enough away from competitors so unforeseen circumstances won't force them to compete at their boundaries. An initial, random alignment as shown in Figure 1a is probably most likely. So long as $F/v\leqslant .1104$, excess profits will continue to be earned, and new firms will continue to enter the plane. If

[1]If the linear demand curve is of the following form, $q=a-bp^*$, where p^* is the delivered price, and $p^*=P_M+Tr^*$ where P_M is the mill price, T is the transportation cost per mile per unit of output, r^* is the distance, m^* is the marginal production cost and v^* is the customer density, then the integrand in equation (1) can be grouped as follows:

$$\left(\frac{a^2}{b}v^*\right)\left[\left(\frac{b}{a}\right)P_M-\left(\frac{b}{a}\right)m^*\right]\times\left[1-\left(\frac{b}{a}\right)P_M-\left(\frac{b}{a}\right)Tr^*\right]$$

For the normalized demand function, redefine $P=(b/a)P_M$, $m=(b/a)m^*$, $r=(b/a)Tr^*$. Furthermore, $r^*dr^*d\phi=(a/bT)^2r\,dr\,d\phi$, so $v=(b/T^2)(a/b)^4v^*$.

[2]Thus $P=P_M/(a/b)=1/4$ means the optimal mill price should be one quarter the reservation price. $B=3/4=r_{Max}=r^*/(a/bT)$ means the optimal service boundary should be three fourths of the distance where demand would fall to zero at a zero mill price. $G_c=.1104[a(a/b)(a/bT)^2v^*]-F$ implies that the operating profit should be approximately 11 percent of the hypothetical maximum which would result if all customers purchased their maximum amount a, paid their maximum price (a/b), and the area served was the hypothetical limit arising from zero mill price, (a/bT). Notice that if fixed costs exceed 11 percent of this hypothetical maximum, producers will go out of business in the long run.

F/v is large and close to .1104, a point may be reached where the packing of spatial monopolists, each serving their own optimal circular markets, may become so tight that it becomes unprofitable for additional firms to enter, that is, new entrants would not be able to find enough customers within their maximum service boundary B, in order to cover fixed costs.

It is at this point that assumption 3 (in Table 1) from traditional location theory usually bails us out. Since relocation is assumed costless, when additional firms threaten to enter, existing firms are assumed to relocate until adequate room is made for the new entrant. However, existing firms neither gain nor lose by the move. It is only through this constant, costless reshuffling that traditional location theory would have us envision new entrants forcing firm relocations into a tight packing like the square configuration shown in Figure 1b. But this isn't good enough. There is still room enough for more firms, and traditional theory would have us believe there would be further rearrangements until the tightest possible configuration, the hexagonal closest packing shown in Figure 1c, is achieved. Note, if our assumption 3, that no firm will relocate unless it can earn strictly greater profits is made, then the square configuration of spatial monopolists in Figure 1b may never be converted to the hexagons in Figure 1c. This is true, because unless existing firms relocate, the most profitable spot for a new entrant is in the interstitial, unserved areas of Figure 1b. But, with F/v close to .1104, there are not enough customers in that space to break even; then no additional entry will occur!

So, under the assumption that some benefit must accrue to the producer in order to motivate relocation, we can't be sure that the hexagonal packing of Figure 1c will be achieved. We can't even be sure a square initial packing like Figure 1b will be obtained. Whatever forces lead to these configurations, they are outside the scope of the assumptions made here, but further inquiry into key determinants of initial market shapes would be the topic of a separate paper.[3] We will merely assume, for a starting point, that either square or hexagonal configurations of spatial monopolists are observed, since for sufficiently large values of $F/v \leq .1104$ either configuration is stable. We will concentrate on the form of subsequent entry into both of these configurations as changing parameter values render further entry profitable.

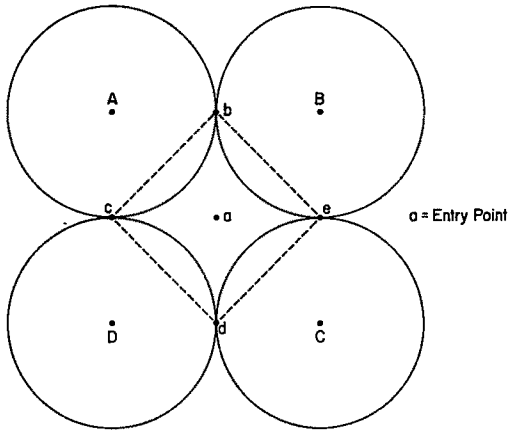

FIGURE 2. ENTRY INTO A SQUARE PACKING OF SPATIAL MONOPOLISTS

C. *Entry Into the Square Lattice*

The possibility of entry into the square lattice of circles is determined by the size of F/v, the ratio of fixed costs to customer density. Consider Figure 2 where only four of the circles are drawn. If entry is possible it will occur at the center of the interstitial area at point a.[4] The dotted line $bcde$ depicts the square market which will occur when a firm enters at a and the original firms, A, B, C, D match the new firm's price; the market will be determined by the locus of points equidistant from nearest neighbors. Hence the

[3]If one uses the existence of cultural or production centers or the shape of a transportation network as an argument for a particular initial geometric alignment, one is violating the original von Thünen assumptions of an undifferentiated plane with uniform customer density and equal hauling costs in all directions.

[4]This would be a consequence of our assumptions about the entering firm's conjectures listed in Table 1 under 5a and b for any shaped demand curve. For the linear demand curve we select, it can be shown that the center of the interstitial area is the most profitable entry point for even a single entrant so long as the entrant anticipates that existing firms will adjust their prices in response to that entry.

boundary between firm a and firm A will be line b–c, etc. The radius of the new market area is $3/4 \cdot 1/(2)^{1/2} = .5304$, if entry started from a tight square packing of spatial monopolists, each with radius 3/4. We must now investigate the range of F/v under which firms can profitably enter at point a to serve the square of that radius. This requires the profit expression for a square:

$$(2) \quad G_S = 8\int_0^{\pi/4}\int_0^{\frac{h}{\cos\phi}} vP(1-P-r)\,dr\,d\phi - F$$

where h = radius of market area.

Maximization of (2) with respect to P yields

$$(3) \qquad P = .5 - .3826h$$

Substituting (3) into (2) and solving yields an equation for profit in terms of h alone:

$$(4) \quad G_s = v(h^2 - 1.5304h^3 + .5855h^4) - F$$

Investigating the properties of (3) and (4) reveals a complication; when $h = .5304$ the price established in (3) will exceed the reservation price at the corners of the square market. Demand will fall to zero and result in a rounded square market after the first round of entry. This means that the firms will serve a market which has part of its boundary determined as the minimums of points equidistant from nearest neighbors and partly as a circular segment the radius of which is the distance at which demand falls to zero at the mill price selected. Hence the firms trade off customers for profits by optimizing their mill price to determine the profit-maximizing rounded square. The tedious mathematics for the configuration of rounded squares are available from the authors on request. There we show that unless $F/v \leq .0881$, the original square lattice of circles is stable in the sense that any new entrant will lead to the unprofitable operation of one or more firms, and one will subsequently leave. However, when $F/v <$ .0881, the first wave of entry will occur. Existing firms will not find it profitable to relocate; instead they will respond to entry by changing price.

When F/v is low enough, there will be third round of entry at the vertices of th square territories left after the second roun of entry. This time the entire square will b served as equations (3) and (4) apply. Thi third round of entry will result in squares o radius $h = .5304/(2)^{1/2} = .375$. Once again th appropriate response of the round two firm is a price response, not a relocation respons — the market areas of the new and old firms will be identical in size, hence there is nowhere to relocate. Using (3), $P = .3565$, and equation (4) yields the triplet $(P, h, G_s) = (.3565, .375, .0715v - F)$. Therefore $F/v \leq$ .0715 must prevail before the third round of entry can begin. If so, then a new square array of markets of radius .375 will result.

A countably infinite number of entry rounds is possible as F/v falls to zero, and the first ten are listed in Table 2. Each market size has a range of F/v in which it is immune to long-run profitable entry even though positive profits are being earned. Thus for most parameter values, we have a situation of persistent, long-run, extra-normal profits even though costless entry is permitted.[5]

D. *Entry into the Hexagonal Lattice*

In a previous paper, we explored and developed the conditions for sequential entry into an initial, hexagonal closest packing of spatial monopolists as depicted in Figure 1c. By geometry, one can show that the radius of the hexagonal market shapes following the first round of entry will be .433.[6] To see what value of F/v is required for entry we consider the profit expression:

$$(5) \quad G_H = 12\int_0^{\pi/6}\int_0^{\frac{h}{\cos\phi}} vP(1-P-r)\,r\,dr\,d\phi - F$$

[5] Our earlier paper showed a similar result for hexagonal configurations.

[6] We also showed elsewhere that the rounded hexagon market shape, originally hypothesized by Beckmann, is not possible under sequential competitive entry; rounded hexagons are only possible under a multiplant monopoly market organization. Thus in this analysis, the parallel to the rounded square shape is not possible under any set of parameter values.

TABLE 2—COMPARISON OF MARKET AND WELFARE MEASURES UNDER SEQUENTIAL COMPETITIVE EQUILIBRIA

F/v Range	Entry Round	Market Shape[a]	Firms per Unit Area[b]	Radius	Price	Range of Average Profits per Capita ($\pi PA/v$)	Average Consumer's Surplus per Capita (CSA/v)	Range of Average Welfare per Capita (WPA/v)
CASE I: Square Closest Packing								
(.1104,.0881]	1	C	1	.75	.250	(0,.0099]	.0368	(.0368,.0467]
(.0881,.0715]	2	RS	2	.5304	.298	(0,.0148]	.0552	(.0552,.0700]
(.0715,.0447]	3	S	4	.375	.357	(0,.0476]	.0693	(.0693,.1169]
(.0447,.0258]	4	S	8	.2652	.399	(0,.0672]	.0823	(.0823,.1495]
(.0258,.0142]	5	S	16	.1875	.428	(0,.0825]	.0931	(.0931,.1756]
(.0142,.0076]	6	S	32	.1326	.449	(0,.0938]	.1016	(.1016,.1954]
(.0076,.0040]	7	S	64	.0938	.464	(0,.1024]	.1081	(.1081,.2105]
(.0040,.0020]	8	S	128	.0663	.475	(0,.1091]	.1128	(.1128,.2219]
(.0020,.0010]	9	S	256	.0469	.482	(0,.1136]	.1163	(.1163,.2299]
(.0010,.0005]	10	S	512	.0334	.487	(0,.1169]	.1188	(.1188,.2357]
$\to 0$	∞	S	∞	0	.5	.125[c]	.125	.250
CASE II: Hexagonal Closest Packing								
(.1104,.0785]	1	C	1.2	.7500	.250	(0,.0164]	.0425	(.0425,.0589]
(.0785,.0367]	2	H	3.5	.4330	.348	(0,.0644]	.0664	(.0664,.1308]
(.0367,.0145]	3	H	10.4	.2500	.412	(0,.1025]	.0870	(.0870,.1895]
(.0145,.0053]	4	H	31.2	.1443	.449	(0,.1275]	.1018	(.1018,.2293]
(.0053,.0019]	5	H	93.5	.0833	.471	(0,.1437]	.1110	(.1110,.2547]
(.0019,.0006]	6	H	280.6	.0481	.483	(0,.1531]	.1167	(.1167,.2698]
(.0006,.0002]	7	H	841.8	.0278	.490	(0,.1587]	.1201	(.1201,.2788]
(.0002,.0001]	8	H	2,525.4	.0160	.494	(0,.1620]	.1222	(.1222,.2842]
$\to 0$	∞	H	∞	0	.5	.1665[c]	.1250	.2915

[a] C=circle, RS=rounded square, S=square, H=hexagon.

[b] A unit area is defined as the area of the square containing one firm in the square closest packing configuration of circular monopolistic market areas.

[c] These figures are presented as illustrations of limits, only. Realistically, as many firms enter the market and customers can choose from several, the patterns of spatial monopoly will be replaced by competition.

The resulting price formula and profit as a function of h alone are

$$P=.5-.351h \tag{6}$$

$$G_H(h)=v(.865h^2-1.214h^3+.4222h^4)-F \tag{7}$$

Evaluating (6) and (7) at the first round radius, $h=.433$, yields the triplet:

$$(P,h,G_H)=(.348,.433,.0785v-F)$$

Therefore $F/v\leqslant .0785$ is required before the second round of entry can begin. In the range $.0785<F/v\leqslant .1104$ the hexagonal closest packing of circles is stable; entry cannot occur. When $F/v\leqslant .0785$, the first round of entry does occur and leads to a space filling pattern of hexagons of radius .433.

Just as with the square lattice, there is a countably infinite number of possible entry rounds depending on particular parameter values. Each round has its associated range of F/v, and each is characterized by hexagonal markets. The parameter values for the first eight rounds of entry are summarized in Table 2.

Thus, we have confirmed one of Eaton and Lipsey's conclusions in this section, that market shapes other than hexagons will persist and be stable under a different type of sequential competitive entry.[7]

[7] These results can also be shown for far more general assumptions about customer demand, but since a welfare comparison of different market shapes is ultimately made, for expositional simplicity the linear demand function is used throughout.

II. A Comparison of Profits, Consumer's Surplus and Total Welfare under Hexagonal and Square Market Configurations

Since nonhexagonal market shapes are shown to be likely to persist in a competitive spatial economy, it is interesting to compare the welfare implications of alternative shapes with that of the planner's ideal — hexagonal configurations. With households distributed uniformly in the plane, consumer's surplus plus profit per land area can be used as a measure of per capita welfare. The formula for consumer's surplus is derived by aggregating the area under the demand curve above the full price (mill price plus transportation cost) for every consumer in the plane, and the formulas for the three market shapes under consideration are as follows:

$$(8)\quad CS_H = 12v\int_0^{\pi/6}\int_0^{\frac{h}{\cos\phi}} \frac{1}{2}(1-P-r)^2 \times r\,dr\,d\phi \text{ (Hexagon)}$$

$$(9)\quad CS_S = 8v\int_0^{\pi/4}\int_0^{\frac{h}{\cos\phi}} \frac{1}{2}(1-P-r)^2 \times r\,dr\,d\phi \text{ (Square)}$$

$$(10)\quad CS_{RS} = 8v\int_0^{\alpha}\int_0^{\frac{h}{\cos\phi}} \frac{1}{2}(1-P-r)^2 r\,dr\,d\phi + 8v\int^{\pi/4}\int_0^{\frac{h}{\cos\alpha}} \frac{1}{2}(1-P-r)^2 \times r\,dr\,d\phi \text{ (Rounded Square)}$$

$$\alpha = \pi/4.42 = \text{limit of square boundary}$$

In order to compute the per area consumer's surplus, CSA, we divide consumer's surplus by the respective territorial areas. The area of the hexagon of radius $h = 3.464\,h^2$ and the area of the square of radius h is $4h^2$. Using these formulae and profit formulae given in Section I, the welfare comparisons in Table 2 for Competitive Equilibria can be derived. There the price, shape, radius, average consumer's surplus per capita (CSA/v), average profit per capita ($\pi PA/v$), and average welfare per capita ($WPA = CSE + \pi PA)/v$ are listed for the first several entry rounds under hexagonal and square market configurations. The number of firms serving an area equivalent to the square surrounding the circular market area of a single producer in the square closest packing of spatial monopolists are also tabulated. This figure indicates the relative density of firms for various parameter values and market configurations.

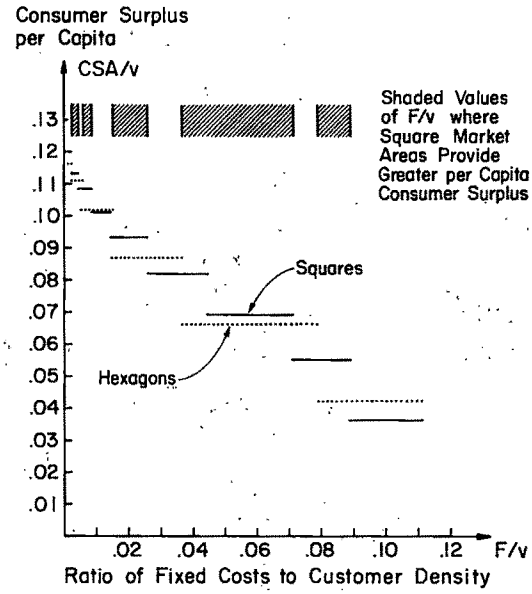

FIGURE 3. CONSUMER'S SURPLUS PER CAPITA FOR SQUARE AND HEXAGONAL MARKET CONFIGURATIONS

For comparison purposes, the key welfare indicators in Table 2 are graphed as functions of F/v in Figures 3 through 5. Since, profit and welfare per unit area increase linearly with F/v for given number of entrants, these relationships are sawtoothed over a wide range of F/v which encompasses several waves of entry. Consumer's surplus per unit area is a step function, since a change in F/v which doesn't encourage new entry causes no change in price or firm service area, and therefore consumer's surplus per unit area is constant over the range of F/v which doesn't encourage entry.

It is noteworthy that neither market shape completely dominates the other over the en-

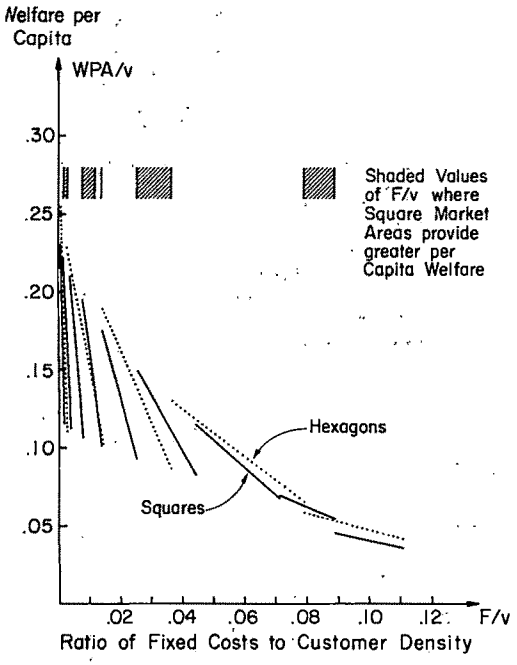

FIGURE 4. WELFARE PER CAPITA FOR SQUARE AND HEXAGONAL MARKET CONFIGURATIONS

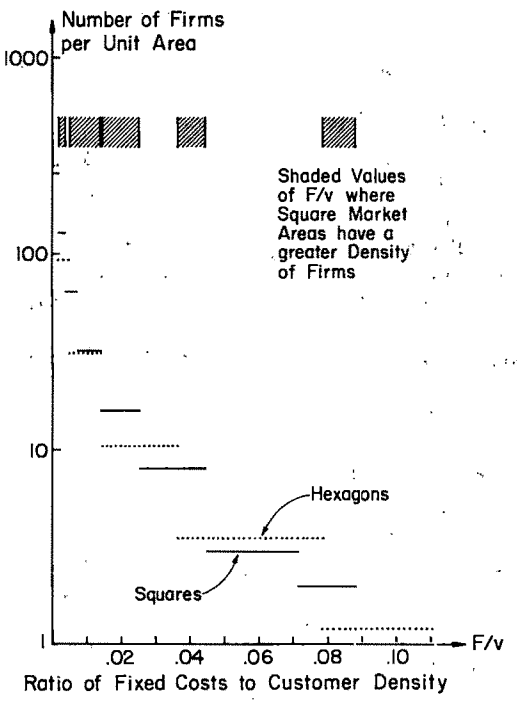

FIGURE 5. NUMBER OF FIRMS PER UNIT AREA FOR SQUARE AND HEXAGONAL MARKET CONFIGURATIONS

tire range of parameter values. For high F/v the hexagon is usually superior, for a range of moderate values of F/v, squares are better; although, the highest level of welfare per unit area oscillates between the two market shapes at particular values of F/v which just permit the entry of a new round of firms for each configuration. Although there are overlaps, entry takes place more rapidly (at higher fixed costs of production and lower levels of customer density) under the square configuration. This is because entry in a square configuration merely doubles the number of producers; whereas entry in a hexagonal grid triples the number of firms. Thus the maximum market radius is smaller under squares under a wide range of parameter values.

Where competitive free entry is tolerated, there may be a welfare incentive for allowing a loose configuration of spatial monopolists in the early stages of development of an economy or at the time of the introduction of a new industry even though there are initial losses in welfare. The benefit occurs as fixed production costs decline or customer density increases. As F/v falls, the spatial economy with square market areas can absorb the entry of new producers more rapidly. This leads to all customers being served at an earlier stage of development, to shorter average transportation distances, and therefore to smaller deadweight losses for society. Thus, while the well-known social benefits of an optimally packed, hexagonal configuration of producers can always be achieved in a planned economy, in a competitive economy with natural market forces and free entry governing location patterns, a square configuration of firms can be socially preferable for a wide range of parameter values that might be observed in the middle stages of development of a new product.

III. Conclusions

Under demand and conjectural variation assumptions which are quite standard in location theory and assuming sequential entry by firms which takes place only when they expect post-entry profits, we confirm that nonhexagonal market shapes can persist in

equilibrium in a market with free entry. We emphasize that the forces leading to square configurations, as an example, are the accident of some initial market shape and the presumption of sequential (rather than simultaneous) entry of new firms as underlying technological costs decline and customer density increases. Finally, for a wide range of values for these technological and demographic parameters, we show that in a competitive market, square configurations may be preferable; only in a planned economy do hexagons always produce higher welfare.

APPENDIX: LIST OF SYMBOLS

q = quantity demanded per customer.
P = mill price per unit (normalized).
r = distance from producer to customer (normalized).
π_A = anticipated profits in new location.
π_0 = profits in current location.
ϕ = angular measure in the plane.
v = population density (normalized).
C = total cost.
m = marginal cost (normalized).
Q = total output of firm.
F = fixed cost.
B = market radius (normalized).
p^* = delivered price.
P_M = actual mill price.
r^* = actual distance from producer to customer.
m^* = actual marginal cost.
v^* = actual population density.
T = actual transportation cost per mile per unit of output.
a, b = parameters of the demand equation.
G_c = profit per firm serving a circular market area.
G_S = profit per firm serving a square market area.
G_H = profit per firm serving a hexagonal market area.
h = shortest market radius.
CS_H = consumer's surplus in hexagonal market.
CS_S = consumer's surplus in square market.
CS_{RS} = consumer's surplus in rounded square market.
πPA = profit per unit area.
CSA = consumer's surplus per unit area.
WPA = total welfare per unit area.

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Job Search and Vacancy Contacts: Note

By JOHN M. BARRON AND OTIS W. GILLEY*

The traditional environment of job search is summarized by the following statements in Jeffrey Hall et al.: "An individual is seeking employment in a market in which jobs are homogeneous in all nonwage attributes. Since he does not know which wage is being offered by which prospective employer, but only the distribution function F of wages, he proceeds by randomly applying for positions, one at a time" (p. 134). Early research in job search emphasized the emergence of the reservation wage property as an optimal search strategy in such an environment.[1] Recently, the rate at which employers are visited to sample wage offers has entered the optimal search strategy in the form of choice of search intensity.[2]

Two key elements of the recent job search models, diminishing marginal returns to search intensity in the production of wage offers and a search strategy limited to a random sampling of employers, are examined in this paper. A theory developed by John Seater that predicts diminishing returns to random search among employers across space is tested in Section I for a sample of unemployed who engage in the direct random search strategy. Section II broadens our sample of the unemployed to include those who choose alternative search strategies and indicates the effects of such choices on the number of employer contacts. In Section III, we outline a theoretical framework to view the choice between random and "nonrandom" search across employers and present evidence on labor force transition probabilities supporting the implication that the search choices of recent search models (relative reservation wage and search intensity), not search strategies, remain as key variables affecting labor market outcomes.

I. Search Strategy: The Random Employer Contact Model

An unemployed individual may randomly contact employers to generate employment offers. For such a search strategy, Seater presented a spatial argument for diminishing returns to search intensity. Assume firms are located uniformly across space and are equally likely to make a wage offer when contacted by a searcher. Then diminishing returns follow from the observation that, as more firms are contacted, the individual requires a greater time to contact one more firm since it is a greater distance from home (the point of departure). Seater formalized this process to obtain the following expression:

$$(1) \qquad ln\, N_B = c_0 + \frac{2}{3} ln\, S + \frac{1}{3} ln \frac{B}{X}$$

where N_B is the number of employer contacts made by such an individual per period, S is the number of hours spent per period in search, B/X is a measure of the density of potential employers in the area of search, and c_0 is a constant.[3] Naturally, a coefficient on $ln\, S$ between zero and one is consistent with diminishing returns to search.

In May 1976, the Bureau of Labor Statistics in cooperation with the Census Bureau conducted a special survey of the unemployed.[4] The information collected permits estimation of equation (1). Among the unemployed who reported search activity leading

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[1]A prime example is John McCall. A survey of the job search literature is Steven Lippman and McCall (1976a).

[2]Examples that deal with search intensity include Lippman and McCall (1976b), Dale Mortensen, Barron and Stephen McCafferty, Gilley, and Kenneth Burdett.

[3]This equation is derived from equation (18) in Seater. Using Seater's notation, the constant equals $1/3\ (ln\pi + 2\, ln(3/4) - 2\, ln\tau)$.

[4]A more detailed discussion of the survey including numerous descriptive statistics of the data appears in Carl Rosenfeld.

to employer contacts,[5] 44 percent indicated their most frequent method of contacting employers in a given period of time was to apply directly to employers without suggestions or referrals by anyone. This sample of individuals captures the view of the random employer contact model. For such individuals, a measure of hours spent in search, S, and the number of contacts made with employers, N_B, for the previous four-week period of April 18 to May 15, 1976 is available. Each measure has been converted to a weekly rate.[6] To directly proxy B/X, $CITY$, a dummy variable equaling one if the individual lived in a $SMSA$, is included.

The results of estimating equation (1) with the above measures are

$$(2)\quad \ln N_B = -.06 \underset{(21.13)}{+.45 \ln S} \underset{(2.53)}{+.13\, CITY}$$

$$N=936;\ R^2=.34$$

The numbers in parentheses are the absolute values of the t-statistics. The typical unemployed individual engaged primarily in random search contacted over three employers per week and spent approximately eight and two-thirds hours per week to make such contacts. A 10 percent increase in search intensity, according to equation (2), results in a 4–1/2 percent increase in the number of employers contacted. Our findings support the proposition of diminishing returns to search in that the coefficient on $\ln S$ is between zero and one. But the particular prediction of Seater's model that this coefficient equals two-thirds must be rejected. A coefficient of less than two-thirds would be predicted if firms are not uniformly distributed across space, as is assumed by Seater, but rather more densely populated regions closer to an individual's point of departure. In fact the point of departure may be chosen such that this is the case.

In support of Seater's model, the density of potential employers, as proxied by the dummy $CITY$, does positively affect the number of employers contacted; unemployed individuals searching in $SMSA$'s (59 percent of the sample) contact over 10 percent more employers for a given search intensity.[7]

II. Alternative Search Strategies

The random employer contact search strategy is not chosen as the most frequent method of search by the majority of those unemployed who engage in search activity. Other methods most frequently chosen include a) a self-directed search strategy in which employer contacts are made with the aid of friends or relatives or by placing or answering ads and b) an indirect strategy in which contacts are made through the use of one of two labor market intermediaries, state employment services or private agencies.[8] Thirty-two percent of the unemployed reporting search activity chose the former strategy and 14 percent chose the latter strategy as the most frequent search method.[9]

What are the effects of choosing these nonrandom search strategies on the number

[5]We excluded from those who were surveyed individuals who were unemployed through layoff and not actively searching (6 percent), individuals who did not complete the survey questionnaire (16 percent), and individuals who made no employer contacts (11 percent).

[6]If the respondent was unemployed four weeks or longer, the reported search time and number of contacts were divided by four; if unemployed less than four weeks, the reported measures were divided by the respondents duration of unemployment.

[7]Inclusion of a set of demographic (sex, race and education) and occupational variables in an estimation of equation (1) leaves unchanged the results reported in equation (2). Interestingly, of the new variables only the demographic variable indicating race is significantly different from zero. Other things equal, nonwhites make approximately 25 percent fewer employer contacts. This variable may be a second proxy for the density of potential employers, where past discrimination leads nonwhite individuals to perceive fewer potential employers in a given area.

[8]These strategies could alternatively be called informal and formal strategies, closely paralleling the categories chosen by Albert Rees and George Schultz to characterize search by the employer.

[9]The remaining 10 percent picked from a variety of other search methods as the most frequently chosen. These other search methods were taking civil service tests, checking with a labor union, contacting a community action group, contacting a school placement office, asking teachers or professors for job leads, or a search method that the respondent specified.

of employers contacted? The results of estimating equation (1) for individuals using either random or nonrandom search strategies, with two dummies to indicate choice of self-directed search (SDS) or indirect search (IS) as the most frequent search method, are

$$(3)\quad \ln N_B = \underset{(25.58)}{.03} + \underset{(1.78)}{.42 \ln S} + .07\,CITY - \underset{(9.21)}{.39(SDS)} - \underset{(9.49)}{.52(IS)}$$

$$N = 1923;\ R^2 = .30.$$

An important finding emerges: individuals choosing primarily nonrandom search strategies, other things equal, make significantly fewer employer contacts. Those engaged in self-directed search make 33 percent fewer contacts and those engaged in indirect search make 41 percent fewer contacts. The effects of search intensity and the variable $CITY$ are as expected.

III. A Theoretical Framework for Search Strategy Choice

The above finding raises the question: if nonrandom search strategies reduce employer contacts, then why are they chosen? To answer this question, a closer look at what in fact is being measured by the choice of one of the three search strategies is in order. We have identified individuals as choosing one of n search strategies based on the response to the question, "Which one method did you use most often during search in the prior four week period?" Let us assume that the individual would designate the ith search strategy as being the most frequent if the time spent engaged in the ith search strategy, α_i, is such that $\alpha_i > \alpha_j\ \forall_j \neq_i$. The total time spent engaged in search, S, is then given by $S = \Sigma_{i=1}^{n} \alpha_i$. In the above discussion, n has been set at three.

Let p_i be the probability that an acceptable employment offer is obtained over a period of time of length ε if search time is devoted to the ith search strategy. Assuming independence,

$$(4)\qquad p_i = f_i(\alpha_i), \qquad p = \sum_{i=1}^{n} p_i$$

where p represents the probability of an acceptable employment offer when the length of the period is sufficiently small. For a given search time, let us assume individuals choose search strategies to maximize p.

For the ith search strategy, p_i can be defined by the probability of an employer contact, c_i, times the probability that an employment offer is made, v_i, times the probability that the employment offer has a value at least as great as the reservation value, δ_i. The evidence indicates that if search strategy i refers to random search, then, for a given search time, the choice of random search as the most frequent search method ($\alpha_i > \alpha_j\ \forall_j \neq_i$) results in a greater probability of making a contact.[10] That is, $c_i > c_j\ \forall_j \neq_i$. One implication is that if $v_i = v_j\ \forall_j \neq_i$ and $\delta_i = \delta_j\ \forall_j \neq_i$, then to forego choosing a random search strategy is not optimal.

The above discussion, coupled with the observation that nonrandom search strategies are often chosen, implies that while these strategies reduce the number of contacts, individuals that choose them do so because they either increase the likelihood that an employer contacted will have a vacancy ($v_j > v_i$) or increase the likelihood that an employment offer received is above the reservation value ($\delta_j > \delta_i$).[11] The gains from such information offset the loss associated with fewer contacts: a shorter expected duration of unemployment results for such individuals than if more time was spent in random search. Thus, the choice of indirect search strategies, though significantly reducing employer contacts for a given search intensity, will not necessarily reduce the likelihood of locating employment in a given period. Below we cite evidence supportive of this view.

A sample of the unemployed respondents in the May 1976 survey were interviewed in the June 1976 Census Population Survey. Matching respondents from the May and

[10]It is important to note that the average number of hours per week spent in search does not vary significantly for groups choosing different search strategies.

[11]We ignore the possibility that individuals choosing nonrandom search strategies are less productive in generating employer contacts through random search.

TABLE 1—MEAN VALUES OF INDEPENDENT VARIABLES[a]

Independent Variables	Mean
AGEL=1 if age≤20, 0 otherwise	.28
AGEH=1 if age≥45, 0 otherwise	.16
NWHITE=1 if nonwhite, 0 otherwise	.17
FEMALE=1 if female, 0 otherwise	.54
ONE=1 if first month in CPS sample, 0 otherwise	.19
TWO=1 if second month in CPS sample, 0 otherwise	.16
FIVE=1 if fifth month in CPS sample, 0 otherwise	.19
SIX=1 if sixth month in CPS sample, 0 otherwise	.14
SEVEN=1 if seventh month in CPS sample, 0 otherwise	.14
LAYOFF=1 if on layoff, 0 otherwise	.09
RW[b]=ratio of current reservation wage to estimated market wage	1.03
S=hours per week spent looking for work	8.36
SDS=1 if self-directed search, 0 otherwise	.36
IS=1 if indirect search, 0 otherwise	.16

[a]The sample is participants in the May 1976 Current Population Survey who were unemployed, completed a supplemental questionnaire on current job seeking activities, and participated in the June 1976 *CPS*. Further, the sample is restricted to individuals reporting search choices and selecting strategies discussed in Section II. This consists of 727 individuals. The variables were constructed from the May *CPS* and the job-seeking activities supplemental survey.

[b]The estimated market wage is obtained from a wage equation estimated using *CPS* data on employed individuals. See Barron and Mellow for details on its construction and the justification for the form chosen for *RW*.

June surveys results in a two period longitudinal file of unemployed individuals. A multinomial logit model of labor force status in June (employed, out of the labor force, or still unemployed) as a function of the individual's prior search choices and other variables is estimated. We include variables indicating the search intensity and relative reservation wage of the individual as well as a dummy for whether the individual is on layoff to indicate the possibility of recall.[12] In addition, a set of demographic variables and a set of month-in-sample variables are included; the second group of variables is an attempt to control for what has become known as the "rotation group bias" problem.[13] Finally, dummies indicating whether indirect or self-directed search is the most frequent search method chosen are included. Table 1 describes the independent variables and reports means. Maximum likelihood estimates of the parameters of the logit equations for the sample of unemployed like that in Section II are reported in Table 2. For the first equation, a positive coefficient indicates a direct relationship between that particular independent variable and the log-odds of successfully locating employment versus remaining unemployed. A negative coefficient implies the opposite. The second equation measures the effects on the log-odds of dropping out of the labor force versus remaining unemployed. Because the logit parameters are somewhat difficult to interpret, derivatives evaluated at the means are reported beside the coefficients in Table 2. These derivatives show the impact on the probability of locating employment (first equation) or dropping out of the labor force (second equation) as independent variables deviate from their means.

An important finding is that the time per period devoted to search and the relative reservation wage significantly affect the

[12]Recent search models that discuss the role of such variables include Gilley, and Barron and Wesley Mellow.

[13]See Barron and Mellow. Our findings are unchanged if the additional variables indicating an individual's length of unemployment and his unemployment insurance status are included.

TABLE 2—MULTINOMIAL LOGIT ESTIMATES OF THE EFFECTS SEARCH CHOICES AND STRATEGIES HAVE ON LABOR MARKET STATUS

Independent Variable[a]	$ln\left(\frac{Pr(EMP)}{Pr(UN)}\right)$		Derivatives	$ln\left(\frac{Pr(OLF)}{Pr(UN)}\right)$		Derivatives	X^2
AGEL	.73	(3.16)	.13	.23	(.88)	.003	10.02
AGEH	−.24	(.85)	−.05	.16	(.50)	.02	1.18
NWHITE	−.39	(1.47)	−.07	.02	(.06)	.01	2.31
FEMALE	−.04	(.23)	−.04	1.21	(2.37)	.12	20.88
ONE	−.09	(.30)	−.03	.62	(1.56)	.06	2.83
TWO	−.05	(.15)	−.02	.40	(.94)	.04	.99
FIVE	.12	(.41)	.004	.66	(1.62)	.06	2.64
SIX	−.17	(.52)	−.05	.68	(1.59)	.07	3.23
SEVEN	.12	(.39)	.02	.20	(.43)	.02	.28
LAYOFF	−.25	(.77)	.002	−1.76	(2.37)	−.17	5.93
RW	−.69	(3.05)	−.13	.10	(.93)	.03	10.78
S	.023	(2.69)	.005	−.029	(1.62)	−.004	11.49
SDS	.13	(.64)	.02	.046	(.18)	.001	.41
ID	−.40	(1.42)	−.07	−.15	(.44)	−.004	2.05
Constant	−.50			−2.63			

[a]The dependent variables are *EMP* (=1 if employed in June CPS, 0 otherwise), *OLF* (=1 if out of labor force in June *CPS*, 0 otherwise), and *UN* (=1 if still unemployed in June *CPS*, 0 otherwise). The respective means are .25, .14, and .61. Reported coefficients are maximum-likelihood estimates of the parameters of a multinominal logit model. The absolute value of the asymptotic *t*-statistic (in parentheses) and the derivative of sample means are reported to the right of each coefficient. The X^2 statistic reported in each row tests the hypotheses that all parameters estimated for a given independent variable are zero.

employment probability in the direction predicted by search theory. Yet the method of search chosen does not. Further, a reestimation of this model with the inclusion of the number of employer contacts per period as a determinant of subsequent labor force status rather than search intensity results in an insignificant effect of the number of employer contacts per period on the employment probability. Thus it does appear that those who choose a search strategy that results in fewer employer contacts (indirect or self-directed search strategies) experience a higher likelihood of locating a vacancy given an employer contact and/or of receiving a wage offer greater than the reservation wage given a vacancy is located such that their probability of employment does not suffer. And, the simplified search choices as envisioned by recent search models are the relevant ones to predict labor market outcomes.

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Hedging and the Competitive Labor-Managed Firm under Price Uncertainty

By JOHN D. HEY*

The recent article by Duncan Holthausen constitutes a significant advance for the analysis of the competitive profit-maximizing firm (*PMF*) when operating under price uncertainty. Moreover, Holthausen's work has important implications for the analysis of the competitive labor-managed firm (*LMF*) when operating under similar uncertainty. The purpose of this paper is to draw these implications.

The crucial feature of Holthausen's paper is the incorporation (or introduction) of a *forward* market into the analysis; this market enables the firm, if it so desires, to avoid the problem of future price uncertainty. Let me be more specific. The firm must take its output decision before the future spot price (i.e., the price which will prevail when the output becomes available for sale) is known; thus, there is uncertainty about the future market price. However, there is a forward market in which the firm can contract now, at a fixed price known now, to buy or sell any amount of output for delivery at the future date. The major result of Holthausen's paper is "...that the firm will produce a level of output which depends only on the forward price and is, in particular, independent of the firm's degree of risk aversion and the probability distribution of the uncertain price" (p. 989). Moreover, Holthausen produces some important results concerning the amount that the *PMF* will hedge in the forward market, and concerning whether the existence of the forward market will encourage the *PMF* to produce a greater or lesser output than in its absence.

In order to explore the implications of Holthausen's results for the behavior of the labor-managed firm, I make use of an important device described in my earlier article (1981). Let p and x denote price and output, respectively; let L denote labor input, and $X=x/L$ denote output per worker. In a certain world, the *LMF*'s objective is to maximize net revenue per worker, W, which is given by

$$(1) \qquad W=pX-C(X)$$

where $C(X)$ denotes the *minimum capital cost per worker consistent with producing output per worker X*. Elsewhere, (my 1981 article) I explore the properties of the function $C(.)$; in particular, I show that if the production function is strictly concave, then

$$C'(X)>0 \text{ and } C''(X)>0 \text{ for all } X>0$$

whether labor and capital inputs are variable or whether one of them is fixed.[1,2]

In a certain world, the *LMF* will behave optimally by choosing X such that

$$(2) \qquad p=C'(X) \text{ and } C''(X)>0.$$

The first-order condition simply states that price should be equated with the marginal (with respect to output per worker) capital cost per worker of producing that output per worker.[3] From (2) it immediately follows

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[1]The notation here differs from that used in my earlier work. I have deliberately adopted here a notation which facilitates comparison with the work of Holthausen.

[2]If the production function is strictly quasi concave, rather than concave, $C''(X)$ is not necessarily positive when both inputs are variable, though all the other properties hold.

[3]This is a more general statement of familiar conditions. For example, suppose capital is fixed at $\bar{K}$ (i.e., we are considering the short run). Then $C(X)=R\bar{K}/L$ where R is the price of capital and $X=f(L,\bar{K})/L$ where $f(.,.)$ is the production function. We have $C'(X)=(-R\bar{K}/L^2)(dL/dX)$ and $dX/dL=(Lf_1-f)/L^2$ where f_1 denotes the partial derivative of f with respect to L, that is, the marginal product of labor. Thus $C'(X)=R\bar{K}/(f-Lf_1)$. Condition (2) implies $p=R\bar{K}/(f$

that $dX/dp=1/C''(X)>0$; thus, in a certain world, the *LMF* responds to an increase in output price p by increasing output per worker X. In the short run, when capital is fixed, this leads to the well-known "perverse result" that the supply curve of a *LMF* is downward sloping (since an increase in output per worker X can only be achieved under the usual assumptions by *decreasing* output x and employment L).

Let us now consider our uncertain world — that is, one in which the output price p is uncertain, and in which output x, or equivalently output per worker X, must be chosen before the uncertainty in p is resolved. *In the absence of a forward market*, the *LMF* must choose X so as to maximize

$$E[U(W)] \tag{3}$$

where $U(.)$ is the *LMF*'s von Neumann-Morgenstern utility function, and where W is given by (1). This problem has been studied by several writers, Jacob Paroush and Nana Kahana, Rama Ramachandran, William Russell and Tae Kun Seo, and Timothy Muzondo and in my earlier 1981 article. The main finding of these studies is that the presence of uncertainty has a significant effect on the *LMF*'s output decision, unless the *LMF* is risk neutral. In particular, if the *LMF* is risk averse, then the presence of uncertainty causes the firm to choose a lower value for output per man X; thus, in the short run, uncertainty induces a higher level of output and a higher volume of employment. Clearly these are significant results.

However, let us now follow Holthausen in supposing that there exists a forward market for the firm's product. Denote the forward price by b, and note that this is certain and known. The firm can contract now to sell or buy any amount of its output in this forward market at the price b for delivery at the future date (when the output becomes available). I follow Holthausen in denoting the amount of the product so hedged in the forward market by h. By the nature of forward markets, there are no restrictions on the value that h may take: in particular, the firm can indulge in speculation ($h>x$ or $h<0$) if it so wishes. Finally, we let $H=h/L$ denote the amount hedged per worker.

The *LMF*'s problem remains that of maximizing (3)—the expected utility of income per worker. But now W is given by

$$W=p(X-H)+bH-C(X) \tag{4}$$

since an amount per worker X is produced (at capital cost $C(X)$ per worker), of which $(X-H)$ per worker is sold at the uncertain future spot price p and the remaining H per worker is sold at the certain forward price b.

The *LMF*'s choice variables are now X and H. The first-order conditions[4] for the maximization are given by

$$\partial E[U(W)]/\partial X = E[U'(W)(p-C'(X))]=0 \tag{5}$$

and

$$\partial E[U(W)]/\partial H=E[U'(W)(b-p)]=0 \tag{6}$$

where expectations are taken with respect to the distribution of p.

Condition (5) is the familiar result that, in the absence of a forward market, implies the consequence discussed above. However, the incorporation of a forward market, and thus the inclusion of (6) changes things considerably. Add (5) and (6) together, to give $E[U'(W)(b-C'(X))]=0$. Now note that, since b and $C'(X)$ are constants, they can be taken outside the expectation sign. Thus $(b-C'(X))E[U'(W)]=0$. But $U'>0$ everywhere, and so we must have

$$b=C'(X) \tag{7}$$

Comparison of (7) with (2) yields the im-

$-Lf_1$), which can be rearranged to give $(pf-R\bar{K})/L=pf_1$ or the more familiar $W=pf_1$. (See James Meade, p. 405.)

[4]Second-order conditions are assumed to hold for risk-averse firms. For risk-neutral and risk-loving firms, second-order conditions do not hold. For details, see fn. 2 of Holthausen.

portant result that, in the presence of a forward market and a forward price b, the *LMF* optimally chooses that value of output per worker X that it would do if output price were certain and equal to b. Thus, as far as the firm's production decision is concerned, the firm acts as if the forward price was the actual output price. This is clearly a result of some significance. In particular, it implies that differences in risk aversion or in expectations about future prices have no effect whatsoever on the firm's output decision.

The introduction of a forward market may thus have a significant effect on the firm's output and employment decisions. Suppose that forward markets are highly competitive so that b is (approximately) equal to Ep (a situation which appears to prevail in practice). Then the results above show that the firm will produce *as if* the output price was known with certainty to be equal to Ep. In the absence of the forward market, as we have already noted, the risk-averse *LMF* will choose a lower value of X than that chosen with a certain price of Ep (and the greater the uncertainty the lower the optimal value of X); in the (capital fixed) short run this implies a higher value of output x and a higher volume of employment L. Thus, in the short run, the introduction of a forward market will have a *depressing* effect on output and employment. This is a further, interesting, example of the type of perverse results that one finds when analyzing the behavior of the labor-managed firm.

The above discussion has concentrated on the production decision. Let us now turn to the hedging decision. Condition (6) can be written[5]

$$(8)\quad E[U'(W)(b-p)]=E[U'(W)](b-Ep) -cov[U'(W),p]=0$$

Since $U'>0$, it follows from (8) that

$$(9)\quad cov[U'(W),p]\gtreqless 0 \text{ according as } b\gtreqless Ep.$$

[5]Here $cov(y,z)=E[(y-Ey)(z-Ez)]$ denotes the covariance between the variables y and z. Note that $cov(y,z)$ can also be written in the forms $E[y(z-Ez)]$ or $E[(y-Ey)z]$.

But $\partial U'(W)/\partial p=U''(W)(X-H)$ using (4). Thus, since $U''<0$ for a risk averter, it follows that

$$\partial U'(W)/\partial p\gtreqless 0 \text{ according as } X\lesseqgtr H,$$

or, equivalently,

$$(10)\quad cov[U'(W),p]\gtreqless 0 \text{ according as } X\lesseqgtr H.$$

Now combine (9) and (10); this yields

$$(11)\qquad X\lesseqgtr H \text{ according as } b\gtreqless Ep.$$

This splendidly simple result sheds light on the hedging decision. It says that the firm will hedge its entire output if and only if the forward price equals the expected future spot price. If the forward price is lower, then the firm will hedge less than its entire output (and may even speculate by setting $H<0$). If the forward price is higher, the firm will speculate by selling forward an amount greater than its output ($H>X$), expecting to purchase the balance in the future at a low spot price.

All of the above material follows directly from the analysis of Holthausen. To avoid unnecessary duplication, I now return to his analysis and carry over his results (which relate to the *PMF*) to the case of the *LMF*. Such a procedure is admissible because (as pointed out earlier in my 1981 article) the problems faced by the *PMF* and the *LMF* are identical in structure. The *LMF* maximizes (3) where W is given by (4), while the *PMF* maximizes

$$(12)\qquad E[U(w)]$$

where w is given by

$$(13)\qquad w=p(x-h)+bh-c(x).$$

Here w denotes profit (denoted by π by Holthausen), and $c(.)$ is the conventional minimum cost function. Note the crucial distinction between the lower case w, x, h and $c(.)$ for the *PMF* (profit, output, amount

hedged and total cost) and the upper case W, X, H, and $C(.)$ for the *LMF* (income per worker, output per worker, amount hedged per worker, and capital cost per worker). Note also that the two cost functions $c(.)$ and $C(.)$ have identical qualitative properties.

Comparison of (3) with (12) and (4) with (13) shows immediately that whatever results hold with respect to x for the *PMF* they must also hold with respect to X for the *LMF*. Let me now summarize the remaining important results of Holthausen's analysis (page references are shown in parentheses).

1. *The effect of increasing risk aversion* (p. 991):

(a) If $b<Ep$ then the optimal hedge h increases as risk aversion increases;

(b) If $b>Ep$ then the optimal hedge h decreases as risk aversion increases;

(c) If $b=Ep$ then the optimal hedge is always zero.

2. *The effect of increasing risk*[6] (pp. 991–92): If $h<x$ and if the firm displays constant or decreasing absolute risk aversion, then the optimal hedge h increases as the riskiness of the price distribution increases.

3. *The effect on output of existence of forward market* (p. 992):

(a) If $h>0$ then the existence of the forward market causes the firm to increase x;

(b) If $h<0$ then the existence of the forward market causes the firm to decrease x.

4. *An example* (pp. 992–93) Suppose p is $N(\mu, \sigma^2)$ and $U(w) \propto -e^{-\alpha w}$ $(\alpha>0)$, that is, the firm displays constant absolute risk aversion (with index α). Then $b=c'(x)$ and $x-h=(\mu-b)/(\alpha\sigma^2)$.

All these results hold for the *LMF* as long as x is replaced by X and h by H. Most of the interpretations are straightforward and I leave these to the reader. However, it may prove useful to emphasize one or two consequences. Consider the (capital fixed) short run: in this, X and x must move in opposite directions—to increase output per man X, the firm must decrease output x and employment L. Thus, result 3 above implies that if the optimal hedge is positive, then the existence of the forward market induces the firm to *decrease* output and employment while if the optimal hedge is negative, then extra output and employment is induced. The same results hold in the long run if the production function is such that the firm responds to a price increase in a certain world by lowering output and employment; however, the opposite results hold if the production function has the converse property.

As Holthausen remarks, "These results clearly show that the firm behaves quite differently when forward markets exist" (p. 993). Given that many forward markets do exist in practice, it is clear that Holthausen's work has important implications not only for the behavior of the profit-maximizing firm, but also for the behavior of the labor-managed firm.

APPENDIX: SYMBOLIC NOTATION

C = cost per worker
E = expectation operator
H = hedge per worker
K = capital
L = labor
R = cost of capital
U = utility
W = net revenue per worker
X = output per worker
b = forward price
c = cost
d = differentiation
e = exponential
f = production function
h = hedge
p = future spot price
w = profit
x = output
y = abstract symbol
z = abstract symbol
μ = mean of price distribution
σ = standard deviation of distribution
α = index of absolute risk aversion
π = profit
∂ = partial differentiation
$\propto$ = proportional to

[6] Holthausen mistakenly terms his increase in risk a "Rothschild-Stiglitz" increase; in fact, it is a "Sandmo increase in risk" (see Agmar Sandmo or my 1979 book, p. 129).

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Competitive Equilibria in Uniform Delivered Pricing Models

By TIMOTHY GRONBERG AND JACK MEYER*

Several recent papers concerned with spatial pricing models have characterized in a formal way the free entry competitive equilibria that can arise when firms must select a mill price for their product. To a lesser extent, these equilibria have also been characterized for firms which are permitted to price discriminate across customers according to their location. Very little has been done, however, to present formally the possible free entry competitive equilibria that can arise when the firms in question must charge a uniform delivered price for their product. This latter area is the primary subject addressed in the research presented here. We will use the standard spatial price model assumptions, and also the typical assumptions concerning free entry and competition, to derive a set of uniform delivered prices and distances between firms that can occur as a free entry competitive equilibrium for firms which set uniform delivered prices. As in the mill price model, multiple price and spacing combinations arise as potential equilibria depending primarily on the conjectural variation assumption made by the firms.

Our findings concerning free entry competitive equilibria in uniform delivered price models are quite striking. Three different types of equilibria are found to be possible. One has low prices and large market areas as a result of extreme price competition among sellers. Another, which corresponds to the Löschian model of uniform delivered pricing, has high prices and small market areas. To obtain this equilibrium, collusion on the part the firms with regard to the market area served is assumed. Obviously this then is not a purely competitive model. The third type of equilibrium characterized here involves more than one firm serving the same market area. That is, the market areas associated with individual firms overlap one another in equilibrium. Shared market areas of this sort are not possible in mill pricing models.

Our results are useful for several different reasons. First, uniform delivered pricing seems to be a dominate feature in the marketing of certain products.[1] Hence, a formal characterization of the equilibria that can arise in markets with uniform delivered pricing may be useful in describing the markets for those products. Second, uniform delivered pricing is often the only legal alternative to mill pricing. Thus, in certain instances, firms might have the option of setting either uniform delivered or mill prices, and must decide which is most beneficial. The basic properties of the equilibria that can arise under each of the pricing modes is relevant information in making that decision. This particular application of the results derived here is further explored in a companion paper. Finally, regulators examining the pricing structure in a market may wish to know what the result of imposing a particular pricing mode will be in a competitive equilibrium.

The paper is organized as follows. First, in Section I, the notation and assumptions used are presented. Next, several different conjectural variation assumptions on the part of the firm are discussed and the resulting free entry competitive equilibria characterized. Finally, the comparative static and other properties of the equilibria obtained here are described and contrasted with those obtained in the equivalent mill pricing model. Particular attention is paid to the properties

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[1]See J. Greenhut, M. L. Greenhut and S. Li for survey results which indicate that more than 20 percent of the firms in the United States charge uniform delivered price.

listed by Dennis Capozza and Robert Van Order (1978) as being desirable in a spatially competitive model.

I. Assumptions and Notations

Following the precedent of the basic spatial pricing literature, the following assumptions will be maintained throughout the paper. The basic notation attempts to follow that used by Capozza and Van Order (1978, pp. 897–98) although some changes were necessary.

ASSUMPTION 1: *There is a single commodity that can be produced in one-dimensional space with the same cost function for all firms.*

ASSUMPTION 2: *The cost function has constant marginal and fixed costs:* $C=f+cX$ *where* $X=$ *output;* $C=$ *production cost;* $f=$ *fixed cost;* $c=$ *marginal cost.*

ASSUMPTION 3: *Transport cost per unit distance is identical between any two points and is equal to t dollars per unit distance.*

ASSUMPTION 4: *Potential customers occupy a homogeneous unbounded line at uniform density D.*

ASSUMPTION 5: *All customers are identical and have a demand curve for x that is linear in delivered price* $x=a-bp=a-b(m+tu)$, *where* $p=$ *delivered price;* $m=$ *mill price;* $u=$ *distance to the firm; and* $a, b>0$.

ASSUMPTION 6: *Firms set a uniform delivered price p and are willing to sell to a distance of* $(p-c)/t$.

ASSUMPTION 7: *Firms continue to enter or exit until profits for all firms are equal to zero.*

Our assumptions differ in two ways from those made by Capozza and Van Order in their analysis of mill price competitive equilibria. One difference is Assumption 6, where firms are assumed to set uniform delivered prices rather than mill prices, and to sell to distances where gross profits are nonnegative. The other change, the assumption of one rather than two-dimensional markets, was made in order to simplify the presentation. For our purposes, linear market areas are sufficiently rich to allow discussion of the points we wish to raise. Furthermore, the algebra is slightly less cumbersome, especially in the discussion of overlapping market areas. Thus, we will focus on the one-dimensional case.

II. Free Entry Competitive Equilibria

The free entry competitive equilibria in uniform delivered pricing models which we are going to consider are essentially defined by the following three conditions. First, the firms are assumed to have fixed locations, equal distances apart along the line that represents the spatial market, and to charge the same price. Second, the actual profits obtained by all firms are assumed to be zero. Finally, each of the firms in question are assumed to be maximizing profits for their perceived profit function. These are the same three conditions used by Capozza and Van Order (1978) in deriving a series of free entry competitive equilibria for firms which set mill prices. The main implication of these assumptions is that it allows us to follow Capozza and Van Order and focus on the "representative firm" in the derivation of the equilibrium.

The profits to a single firm charging uniform delivered price p and serving *all* customers to a distance R in each direction is given by

$$(1)\quad Y_u=2D\int_0^R(p-c-tu)(a-bp)\,du-f$$

$$=2D(a-bp)\left[(p-c)R-\frac{tR^2}{2}\right]-f$$

For each level of fixed costs, one can set this function equal to zero and obtain a set of uniform delivered prices p, and distances R, which yield zero profits to firms charging that price and serving market area of length R in each direction. A typical zero-profit locus (ZPL) in (distance, price) space for fixed costs f_0 is presented in Figure 1. A portion of the ZPL associated with fixed

cost levels f_1 and f_2 are also shown assuming $f_2<f_1<f_0$. Only the portions of the *ZPL* above $p=c+tu$ and below $p=a/2b+c/2+tu/4$ are needed in the analysis. These two prices are the price at which gross profits from selling to distance u becomes zero, and the monopoly price for selling to distance u, respectively.[2] It is reemphasized that the above zero-profit market area and price level combinations assume that the firm serves *all* customers in the given market area. Later we will consider a situation where this is not the case.

The third condition employed in defining an equilibrium is that of profit maximization on the part of the individual firms. This condition takes on different forms depending on what the firm conjectures concerning the reaction of its competitors to a change in its own price. Since this issue is the basis for the three types of equilibria found here, it will be discussed in detail.

Consider the simplified case of two firms charging uniform delivered price p, located a distance $\bar{U}$ apart, and serving only the customers located on the line between them. Two situations are possible; either the firms' desired market areas overlap, or they do not. In the latter case, it must be that $\bar{U}/2>(p-c)/t$, and each firm can act as if the other does not exist. The solution to this monopoly problem is well known and need not be detailed here.[3] In what remains, we assume the more interesting case, that the desired market areas overlap.

In this setting with overlapping market areas, each firm desires to serve to a distance $(p-c)/t$ which is greater than $\bar{U}/2$, and a conflict arises between the two firms as to who will sell to the customers in the disputed region. It is precisely the resolution of this conflict that leads to the three types of equilibria that are developed here.

The first type of equilibrium we wish to consider involves extreme price competition. It is assumed that the individual firm believes that its competition either does not change its price or changes it by an amount less than one's own price change. Under these circumstances, a firm can resolve the problem of overlapping desired market areas by simply cutting its price by any amount $\varepsilon>0$. This price change, no matter how small, is sufficient to allow the firm to totally capture the disputed market area. Assuming both firms believe this to be true, equilibrium can only occur when both firm's prices have fallen to the point where their desired market areas no longer overlap. That is, p must fall until $p=t\bar{U}/2+c$ or in another form until $(p-c)/t=\bar{U}/2$. If one generalizes this to the representative firm, then entry or exit occurs to alter $\bar{U}$ until zero profits are earned by the firms. In Figure 1, the intersection of the line *cM* with the *ZPL* associated with fixed costs f_2 represents such an equilibrium. This point (R_c, p_c) represents a uniform delivered price p_c and spacing between firms $\bar{U}=2R_c$, which is profit maximizing to firms making the above conjecture, and yields zero profits when fixed costs are f_2. To solve for (R_c, p_c) explicitly involves finding the roots of a cubic equation in R and will not be detailed here.

The two remaining free entry competitive equilibria we wish to discuss both involve the conjecture on the part of firms that competitors exactly match any price change. With this unitary conjectural variation assumption, the incentive to cut prices described in the last paragraph no longer exists. Some other assumption concerning the resolution of the conflict over desired market areas is required. Two different models will be discussed in this regard.

If the two firms overtly collude, deciding to split the market between them exactly, each taking the portion closest to themselves, we then have firms acting as if their market area is fixed at $\bar{U}/2$. This assumption of a fixed market area is precisely the Löschian model of a spatially competitive firm. The profit-maximizing uniform delivered price is $p=a/2b+c/2+t\bar{U}/8$ which can be found by maximizing (1) with respect to p holding R fixed at $\bar{U}/2$. Again considering this to be the behavior of the representative firm, entry

[2]See Capozza and Van Order (1978) for a similar but more detailed discussion of the economically relevant portions of the zero-profit locus for the mill pricing case.

[3]This result is available in Martin Beckmann and numerous other places.

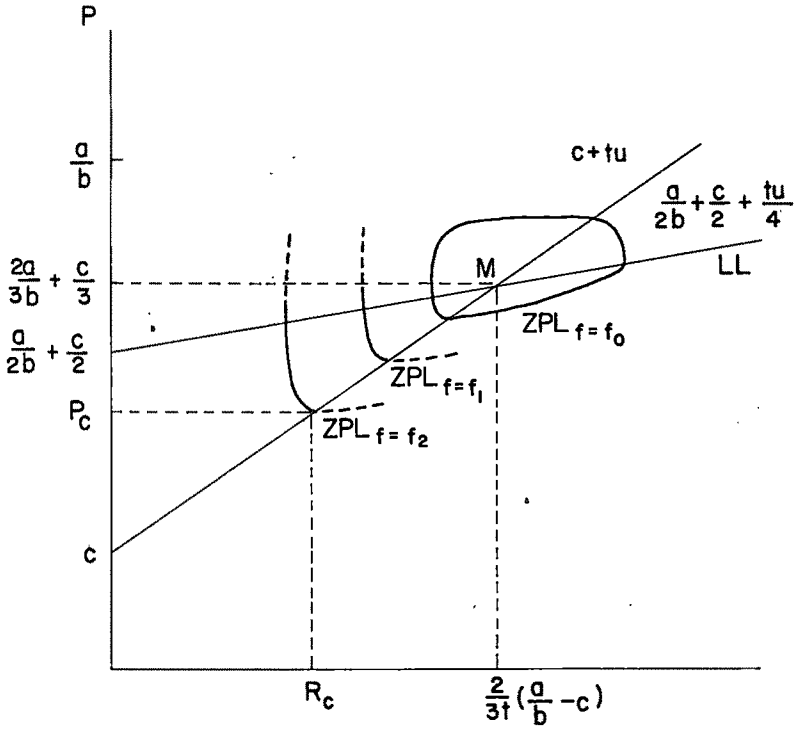

FIGURE 1

or exit occurs adjusting $\bar{U}$ until zero profits are earned. This particular equilibrium is represented in Figure 1 as the intersection of the line *LL* with the *ZPL* associated with the given level of fixed costs. Note that for any given level of fixed costs, this equilibrium price is higher and the market area is smaller than that found earlier. We reemphasize that in order to obtain this Löschian model of an individual firm in a setting with free entry and exit, collusion with regard to market areas was used.

In the final model considered, the assumption of price matching is maintained, but the customers in the disputed market area are assumed to randomly select the firm with which they do business. Since price to the customer is the same for each firm, this is an acceptable assumption. Under this assumption, (1) is no longer the profit function to the firm since the firm no longer serves all customers in its market area. This also implies that Figure 1 no longer represents the *ZPL* to the firm. The new expected profit function for the representative firm located a distance of $\bar{U}$ from each competitor and desiring to serve a distance of $(p-c)/t > \bar{U}/2$ in each direction is given by

$$Y_p = 2D\int_0^{\bar{U}-(\frac{p-c}{t})}(p-c-tu)(a-bp)\,du$$

$$+D\int_{\bar{U}-(\frac{p-c}{t})}^{(p-c)/t}(p-c-tu)(a-bp)\,du-f$$

which yields

$$(2)\quad Y_p = \frac{tD}{2}(a-bp)\left(-\bar{U}^2+4\bar{U}\left(\frac{p-c}{t}\right)-2\left(\frac{p-c}{t}\right)^2\right)-f$$

To interpret this profit function, the first portion gives profits to the firm from the uncontested portion of its market area. The second portion gives the expected profits

from the randomly assigned customers in the shared market area. We have assumed that $(p-c)/t<\bar{U}$ so that multiple overlaps need not be considered. The profit function (2) is differentiable in p for p in the specified range $\bar{U}/2<(p-c)/t<\bar{U}$. The first and second derivatives of this profit function are given below as (3) and (4).

$$(3)\quad Y_p'=\frac{tD}{2}\left[(a-bp)\left(\frac{4\bar{U}}{t}-\frac{4}{t}\left(\frac{p-c}{t}\right)\right)-b\left(-\bar{U}^2+4\bar{U}\left(\frac{p-c}{t}\right)-2\left(\frac{p-c}{t}\right)^2\right)\right]$$

$$(4)\quad Y_p''=2D\left(\frac{-a}{t}+\frac{3bp}{t}-2\bar{U}b-\frac{2bc}{t}\right)$$

Now $Y_p''<0$ for all $p\varepsilon[c+t\bar{U}/2, c+t\bar{U}]$ and Y_p' attains the value of zero in this interval. Thus, the solution to $Y_p'=0$ yields the profit-maximizing price in the specified interval. Entry or exit now occurs to drive the profits of this representative firm to zero. By evaluating Y_p' at both $c+t\bar{U}/2$ and $a/2b+c/2+t\bar{U}/8$, one can see that for any spacing this optimal price lies between the prices associated with the two equilibria found earlier. In fact, the equilibrium spacing can also be shown to lie between the equilibrium spacings of the previous two models. Since the zero-profit locus associated with profit function (2) is not that presented in Figure 1, this third equilibrium cannot easily be compared with the others in a graphical manner.

In summary, considering only equilibria involving equal spacing between firms, three different types of equilibria were found for uniform delivered pricing models with free entry and competition. The first involved extreme price competition and yielded an equilibrium with large market areas and low prices. The second involved a collusive market-sharing assumption and yielded an equilibrium with high prices and small market areas. This model presented the individual firm as acting as if market areas were fixed, the Löschian case. Finally, the third type of equilibrium involved shared market areas. In this model, the overlapping markets were used to reduce customer density and hence drive profit to zero. Our next task is to discuss more fully the properties of these equilibria in light of Capozza and Van Order's (1978) criteria for acceptable models of spatial pricing. This occurs in the next section.

III. Properties of the Competitive Equilibria

Capozza and Van Order (1978) have enumerated a set of criteria that equilibria in a reasonable model of spatial competition should satisfy. Although they were working in the mill price setting, the criteria appear to be useful in evaluating uniform delivered price models as well. The following two criteria will be specifically examined here.

C1: *As fixed costs f, or transport costs t go to zero, equilibrium price should approach marginal cost c.*

C2: *As costs (fixed, marginal or transport) rise, the equilibrium price should rise.*

Criterion 1 states that if either of the two variables which give importance to spatial models of the firm go to zero, then a model of spatial competition should have an equilibrium price which approaches the nonspatial competitive equilibrium price. That is, the spatial equilibrium price should approach marginal cost. This criterion is concerned with properties of the spatially competitive model as space becomes unimportant. Criterion 2 has a different slant. It states that the comparative static effect of changes in cost variables should be in the same direction as found in nonspatial models. That is, cost increases should, in free entry competitive equilibrium, imply price increases. The fact that C2 is not satisfied in many mill and discriminatory pricing models is well known and has been termed the "perverse" effects of space. Refer to papers by M. L. Greenhut and H. Ohta, M. L. Greenhut et al., and Capozza and Van Order (1977a, b) for this discussion.

Examining the models presented here, we find that in the first type of equilibrium, extreme price competition forces the free entry competitive equilibrium price to satisfy $p=(t\bar{U}/2)+c$. Thus, as $t\to 0$, price indeed approaches marginal cost. Also, since the profit function (1) is increasing in p and R, a

decrease in fixed costs requires a smaller market area for any given level of p if zero profits are to be maintained. Hence, as presented in Figure 1, the ZPL expand toward the vertical axis as fixed costs fall. Thus, $\bar{U}$ goes to zero as f goes to zero and C1 is satisfied. By similar argument C2 is also demonstrated to be satisfied.

The equilibria of the second type, those associated with the Löschian assumption of fixed market areas, do not satisfy C1. To see this, note that the equilibrium price was calculated to be $p=a/2b+c/2+t\bar{U}/8$. Obviously as $t\rightarrow 0$, this approaches $a/2b+c/2$ which is the monopoly price in the nonspatial model. As fixed costs and $\bar{U}$ go to zero, this same price is approached. Thus, C1 is not satisfied. On the other hand, C2 is satisfied as can readily be determined. This Löschian model is indeed noncompetitive as the effects of space are deleted. Capozza and Van Order (1978) found a similar lack of competitiveness in the mill price case. Contrary to their results, however, no perverse price effects of shifts in cost parameters are present for the uniform delivered pricing case.

The uniform delivered pricing model yielding equilibria with overlapping market areas is not so easily treated. This is because no explicit solution for the equilibrium price was found. The bounds on the price indicated earlier make it easy to show that C1 is satisfied. That is, the interval that the price was restricted to fall in, $[c+t\bar{U}/2, c+t\bar{U}]$, shrinks to the point c as either t goes to zero or as f goes to zero and hence $\bar{U}$ as well. To check C2 for this model requires total differentiation of the first-order condition defining the optimal price. After tedious calculation, it can be shown that C2 is satisfied.

In summary, uniform delivered pricing models yield at least three equilibria, none of which exhibit the "perverse" comparative static effects found in many mill or discriminatory pricing models. Furthermore, two models are competitive as the importance of space goes to zero. The Löschian case is clearly not a competitive model in the uniform delivered price setting.

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A Note on Estimating Treatment Effects

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In a recent 1978 article, Michael Keeley, Philip Robbins, Robert Spiegelman, and Richard West (KRSW) suggest an ingenious method for dealing with a potential source of bias in estimating treatment effects in a negative income tax (*NIT*). In this note, I make two points. First, their methodology can be modified and applied to a broader range of topics than experimental *NIT*s. A modified version of their technique, therefore, deserves wider attention. Second, both income and wage effects presented in their paper are not consistent estimates. Using a consistent estimator of the income effect significantly modifies their conclusion about the work response in the *SIME-DIME* experiments.

I. Source of Bias

The problem of selectivity bias may arise if, in estimating the effects of some treatment (for example, *NIT* payment) on future behavior, one does not correct for the fact that the size of the treatment itself depends on past observations of the behavioral variable being studied. This may occur for two reasons. The behavioral variable may affect assignment between the control and experimental groups or it may affect the size of the treatment received by those in the experimental group. Since the methodology for dealing with the first source of bias is both well known[1] and properly followed by KRSW, I focus on the second source of bias.

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[1]See Burt Barnow, Glen Cain, and Arthur Goldberger. The analysis in this note is an extension of their methodology. Robert Moffitt offers an alternative approach.

The following model is useful in understanding why the bias arises. Suppose we want to estimate the effect of treatment, T, on some behavioral variable Y. Let Y_e be the behavior after the experiment and Y_p be the pre-experimental behavior. The following three equation model summarizes the interrelationships:

$$Y_p = f(X_p) + \delta + \mu_p \tag{1}$$

$$Y_e = f(T, X_e) + \delta + \mu_e \tag{2}$$

$$T = g(Y_p) + \eta \tag{3}$$

where X is a vector of measured variables, δ is a permanent unobserved characteristic of the individual, and μ and η are random errors. Subscript p refers to the pre-experimental period (when T is equal to zero) and subscript e refers to the experimental period. In the case of an *NIT* experiment T represents the benefit paid to an individual. It varies with η, the level of the benefit schedule the person is randomly assigned to, and Y_p, the person's pre-experimental hours. Holding wages constant, the latter is inversely related to the benefit since payments are reduced as pre-experimental earnings increase.

The two simplest methods of estimating treatment effects both violate the basic assumptions necessary for consistent estimates. If one computes *OLS* estimates by regressing Y_e on X_e and T, T will not be independent of the error term since δ affects both. Alternatively, if one regresses T against the change in behavior $(Y_e - Y_p)$ then T and the error are not independent due to μ_p.

These three equations show a potential source of bias in estimating *NIT* labor supply responses. Observationally identical people differ widely in the hours they work. Those who are "prone to work" have expected positive disturbances in experimental hours, Y_e. On average, they also have small treatments

NIT benefits) since these depend on pre-experimental earnings and hence hours, Y_p.

Consider other areas where this general problem arises. Some people are more likely to commit crimes than would be predicted on the basis of their measured characteristics. This leads to above average sentences (the treatment). An analysis of recidivism, with length of jail sentence as a regressor, would yield inconsistent estimates of the treatment effect—those prone to crime (for whatever reason) spend more time in jail and commit more crimes after their sentences. Next, consider evaluating the impact of a special reading program. Slow learners may receive extra help. Regressing reading level on amount of help would again lead to inconsistent estimates of the impact of the tutorial program, even if people were randomly assigned to the control group. Obviously, a whole range of topics fit this pattern.

In the following section, I derive a consistent estimator of treatment effects when people are randomly assigned to control or experimental groups but the treatment received by the experimentals depends on their pre-experimental behavior. As might be expected, the estimator is very similar to estimators developed to deal with the assignment problem. In the third section I explain the difference between this and the estimator used by KRSW. I then reestimate their model and discuss the results.

II. A Proposed Estimator

Let D be a dummy variable which takes the value of 1 for persons in the experimental group and 0 for the persons in the control group. Let Y_p^* be the value of Y_p for experimentals: $Y_p^* = D \cdot Y_p$. I will show that if D and Y_p^* are included in the regression, the estimates of treatment effects are consistent. Intuitively, by holding Y_p (for experimentals) constant, we can compare the behavior of persons whose treatment varies only with η.

Assume that equations (1) and (2) are linear in X and T so

$$(4) \quad Y_e - Y_p = f(T, X_e - X_p) + \mu_e - \mu_p$$

can be written as $Y_\Delta = Z\beta + V$

where $V = \mu_e - \mu_p$

$$Z = (T, D, Y_p^*, X_\Delta)$$

$$\beta = (\beta_t, 0, 0, \beta_x)$$

and $E(V'X_\Delta) = 0; \quad E(V) = 0.$

The change in the observable variables X_Δ and the treatment T form the structural relationship. By assumption, D and Y_p^* do not enter the structural relationship. While Z could have been defined as containing only T and X_Δ, entering D and Y_p^* with zero coefficients simplifies notation later.

As I explained earlier, T and V are not independent because T depends on Y_p. Assume that the treatment a person would receive, if assigned to the experimental group, is linear in Y_p.

$$(5) \quad T = D(a + bY_p + \eta) = aD + bY_p^* + D\eta$$

where η is a stochastic term, independent of V.[2] Since the bracketed term is multiplied by D, those in the control group receive zero treatment. For an *NIT*, equation (5) just requires that the benefit schedule be linear.

Consider the following regression:

$$(6) \quad Y_e - Y_p = \hat{\beta}_T T + \hat{\beta}_D D + \hat{\beta}_{Y_p^*} Y_p^* + \hat{\beta}_{x_\Delta} X_\Delta + r \equiv Z\hat{\beta} + r$$

where r is a vector of residuals. The probability limit of the *OLS* estimator is given by

$$(7) \quad plim(Z'Z)^{-1}Z'(Y_e - Y_p) = \beta + plim(Z'Z)^{-1}Z'V$$

[2]Note that the treatment must have a random component if D and Y_p^* are included as regressors. Without η there would be perfect collinearity between T, D and Y_p^*. In the case of the *SIME-DIME* experiments, variations in η reflect variations in the guarantees between plans. In studying criminal activity, T might be the length of sentence which varied with previous criminal activity Y_p, and the severity of the judge, η.

Plim $Z'V$ is not equal to zero; however, writing out the elements of $plim(Z'Z)^{-1}Z'V$ shows that the first element of this vector is equal to zero. The estimator of the coefficient on T is, therefore, consistent.

To see this, first consider $plim(Z'Z)^{-1}$. The upper elements of this symmetric matrix are

$$(8)\quad plim(Z'Z)^{-1}=plim\begin{bmatrix}\Sigma T^2 & \Sigma DT & \Sigma Y_p^*T & T'X_\Delta\\ & \Sigma D^2 & \Sigma DY_p^* & D'X_\Delta\\ & & \Sigma Y_p^{*2} & Y_p^*X_\Delta\\ & & & X_\Delta'X_\Delta\end{bmatrix}^{-1}$$

Substitute equation (5) into the second through fourth elements of the first row.

$$(9)\quad plim(Z'Z)^{-1}=plim\begin{bmatrix}\Sigma T^2 & a\Sigma D^2+b\Sigma DY_p^* & a\Sigma DY_p^*+b\Sigma Y_p^{*2} & (aD+bY_p^*)'X_\Delta\\ & \Sigma D^2 & \Sigma DY_p^* & D'X_\Delta\\ & & \Sigma Y_p^{*2} & Y_p^{*\prime}X_\Delta\\ & & & X_\Delta'X_\Delta\end{bmatrix}^{-1}$$

Notice that except for the first element, the first row is just the second row times a plus b times the third row. Let f_{ij} be the probability limit of the i, jth element of the inverse matrix. It can readily be shown that $f_{12}=-af_{11}$, $f_{13}=-bf_{11}$, and $f_{14}=0$.

Therefore,

$$(10)\quad plim(Z'Z)^{-1}=\begin{bmatrix}f_{11} & -af_{11} & -bf_{11} & 0\\ & f_{22} & f_{23} & f_{24}\\ & & f_{33} & f_{34}\\ & & & f_{44}\end{bmatrix}$$

Next, consider $plim(Z'V)$:

$$(11)\quad plim(Z'V)=plim\begin{bmatrix}plim\,\Sigma TV\\ plim\,\Sigma DV\\ plim\,\Sigma Y_p^*V\\ plim\,X_\Delta'V\end{bmatrix}$$

Substitute equation (5) into the first element of this vector and recall that by assumption $plim\,X_\Delta'V$ is equal to zero:[3]

$$(12)\quad plim(Z'V)=\begin{bmatrix}a\,plim\,\Sigma DV+b\,plim\,\Sigma Y_p^*V\\ plim\,\Sigma DV\\ plim\,\Sigma Y_p^*V\\ 0\end{bmatrix}$$

Postmultiplying equation (10) by equation (12) shows that

$$(13)\quad plim\,\hat{\beta}_T=\beta_T$$

$$(14)\quad plim\,\hat{\beta}_{X_\Delta}=\beta_{X_\Delta}+f_{24}\,plim\,\Sigma DV+f_{34}\,plim\,\Sigma Y_p^*V$$

Therefore, the estimated coefficients on T are consistent but those on X_Δ are not. This makes intuitive sense. We enter Y_p^* to counteract the original bias in the coefficient on T.[4] It accomplishes this but contaminates the other coefficients.

III. KRSW's Results

Keeley et al. estimate the following function:[5]

$$(15)\quad Y_e-Y_p=\hat{\gamma}_T T+\hat{\gamma}_{Y_p}Y_p+\hat{\gamma}_X X+r'$$

[3] If assignment to the control group is random, $plim\,\Sigma DV$ is also zero.

[4] Examination of equations (9) and (11) shows that D and Y_p^* introduce bias, but exactly of the same size and opposite in sign compared with the original bias caused by T.

[5] The analytical model developed in Appendix A of Keeley et al. (1977) is a restricted version of the model they actually estimate. KSRW do not focus on the

It differs from equation (6) by excluding D from the regression and by including Y_p for all observations, rather than just for experimentals.

Viewed in this framework, two points become clear. First, since the two estimating equations ((6) and (15)) are identical if control observations are excluded from the sample, KRSW's equation gives consistent estimates if (and only if) the sample is limited to people assigned to experimental plans. The second point is that, while consistent estimates of the income effect may be obtained, the estimates of the wage effect are inconsistent using either their estimator or the one suggested in this note. This can be seen by recognizing that the payment is represented by T (it varies with Y_p) and the benefit reduction rate is one of the X variables (it doesn't vary with Y_p). Since the wage effect is captured from variations in this X variable, inconsistent estimates are obtained.

While KRSW do not deal with the latter problem, they do acknowledge that the inclusion of observations on controls leads to inconsistent estimates of income effects.[6] In order to gain efficiency, the authors chose not to limit their sample to persons in the experimental group.[7] This decision was based on the finding that inclusion of controls did not affect the coefficients in the male regression very much. This decision is questioned on two grounds. First, the coefficients for wives and for female heads are affected substantially when controls are excluded. Second, their estimator is consistent only if the treatment is a linear function of Y_p. Therefore, persons on declining tax rate plans would have to be excluded to yield consistent estimates. When they are also dropped from the sample the coefficients for all three groups change substantially.

Table 1 gives estimates of income effects for four samples. The wage effects are shown for completeness. They are not discussed since they are inconsistent estimates of the population parameters. All equations include the full list of independent variables described in Keeley et al. (1978). The same data are used. Columns 1–3 show the result of applying KRSW's estimation technique. Column 1, based on the full sample, replicates the results in Keeley et al. (1978). Column 2 excludes people assigned to the control group and column 3 further excludes people assigned to *NIT*s with nonlinear benefit schedules. In column 4, I apply the estimation technique developed earlier in this note to a sample of persons assigned to the linear *NIT* plans and to the control group.

Comparing columns 1 and 2 indicates that KRSW's decision to include persons assigned to the control group was based on incomplete information. They cite the following evidence: "A comparison of least squares estimates for husbands, including and excluding control families, indicates that the coefficients of $\Delta Y_d(H_p)$ and ΔW [the income and substitution effects] differ by less than 10 percent, while the standard errors are 16 percent larger when controls are excluded" (p. 878, fn. 24). Their conclusion based on *OLS* estimates of husbands is not supported when Tobit estimates of each cohort are compared.[8] Including controls changes the Tobit estimates of the coefficient on the change in income from -34.4 to -45.7 for males and from -142.9 to -47.2 for wives. Only female heads show relatively stable coefficients.

However, this is still not the proper basis of comparison since the experimentals still include person on nonlinear *NIT* plans. The estimates are not consistent for them. If KRSW's estimator is used, the proper comparison is between columns 1 and 3. This shows that the coefficients on ΔY_d for wives and female heads in column 3 are much

inherent correlation between T and V, through previous hours worked. Instead they introduce yet another potential source of bias—they assume T is measured with error. In deriving the properties of their estimator they develop a model which is a special case of the model analyzed in the previous section. Rewritten in our notation the model they analyze assumes that $\beta_{x_\Delta}=a=0$ and $V=\mu_e-\mu_p(1+b\cdot\beta_T)$. Their assumptions about β_{x_Δ}, a, or V are not necessary for their proof to go through.

[6]See Keeley et al. (1977, p. 30).

[7]See Keeley et al. (1978, p. 878).

[8]All other equations in their paper use Tobit. The use of *OLS* to reduce costs unfortunately led them astray.

TABLE 1—ESTIMATED WAGE AND INCOME EFFECTS

	KRSW Specification			Modified Specification
	Full Sample (1)	All Experimentals (2)	Experimentals On Constant Tax Rate Plans (3)	Experimentals On Constant Tax Rate Plans plus Controls (4)
Number of Observations				
Males	1592.	846.	467.	1213.
Wives	1698.	912.	499.	1285.
Female Heads	1358.	831.	469.	996.
Coefficient on ΔY_d				
Males	−34.4	−45.7	−83.6	4.6
	(27.3)	(20.8)	(46.5)	(42.7)
Wives	−142.9	−47.2	−31.3	−32.9
	(44.9)	(59.7)	(78.4)	(40.5)
Female Heads	−101.1	−107.3	−69.7	53.0
	(39.4)	(53.4)	(69.6)	(40.4)
Coefficient on ΔW				
Males	83.2	96.0	30.0	−57.3
	(37.1)	(77.4)	(63.5)	(60.2)
Wives	168.0	86.6	−109.5	−37.8
	(91.2)	(101.8)	(153.9)	(85.6)
Female Heads	125.8	87.5	66.9	−91.2
	(65.9)	(78.1)	(103.2)	(68.7)

Note: Standard errors are shown in parentheses. ΔY_d is the change in disposable income which is defined by KRSW as the *NIT* payment at pre-experimental hours. ΔW is the change in wage rate which they define as the change in the effective tax rate multiplied by the pre-experimental wage rate.

closer to zero and the coefficient for husbands is more than twice its value in column 1. The only significant coefficient on ΔY_d is in the male regression.[9]

The view that controls should be excluded from the sample is further supported by an examination of column 4.[10] Persons assigned to the control groups are reentered into the sample and the *OLS* estimator developed earlier is applied. If the control groups' behavior is properly modeled, column 4 should also give consistent estimates and these coefficients should be more efficient than those in column 3. As expected the standard errors of the coefficients are reduced but the coefficients change dramatically. Two out of three are positive and none is significant.

Such large changes in coefficients when the sample is broadened to include persons assigned to the control group are puzzling. Several explanations come to mind. First, the control group may differ from the experimental group in ways not picked up by the assignment variables. Second, the control group's behavior may not have been properly modeled. For example, KRSW assume that ΔW and ΔY_d were zero for controls. A better specification of factors affecting controls might improve the results. This potentially useful exercise is, however, beyond the scope of this limited paper. Finally, it is possible that introducing D and Y_p^* robs ΔY_d and ΔW

[9]This may be partially explained by the fact that the inconsistent slope coefficients lend an upward bias to the standard error of estimate, and hence to the standard errors of the coefficients.

[10]All independent variables, including the assignment variables, used by KRSW except for *DECLINE* and H_p were entered. KRSW start with an equation which has the change in hours worked $(H_e - H_p)$ as the dependent variable. They then add H_p to both sides of the equation. They can do this since H_p already appears on the right-hand side—its coefficient will just be increased by one. Since $D \cdot H_p$, not H_p appears in the equation used to estimate column 4, H_p cannot just be added to both sides. My dependent variable in this equation is, therefore, $(H_e - H_p)$.

of their effects—four variables are now influenced by the assignment to experimental or control status. In fact the coefficient on D is significant in the three equations and the coefficient on Y_p^* is also significant in the males' regression. The correlations of these variables with ΔY_d and ΔW are, however, never larger than .6, making multicollinearity an unlikely explanation of the results.

Whatever the cause of the difference between columns 3 and 4 one should remember that only these two columns give consistent estimates of income effects for the model specified in Keeley et al. (1978). Alternative specifications may yield other estimates. While awaiting the results of further research, I remain leery of drawing conclusions from samples of the *SIME-DIME* experiments which include the control group.

In summary, KRSW introduce previous hours worked into their equation to improve efficiency. They recognize that inconsistent estimates will be obtained if persons assigned to the control group are included in the sample. However, based on partial information, they conclude that entering control observations does not affect their results very much. A reexamination of their data indicates that this is not the case. Using a technique which yields consistent estimates, even when control observations are entered in the sample, leads to the tentative conclusion that the controls differ from the experimentals in ways that have not been fully accounted for in the model. The results based on the experimentals would, therefore, seem to be more reliable.

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The General Nonneutrality of Income and Consumption Taxes: Comment

By J. GREGORY BALLENTINE*

In a recent note in this *Review*, John Whalley demonstrated that under certain conditions an income tax and a consumption tax are equally efficient. The conditions required for Whalley's conclusion, however, make it irrelevant to the current debate over income versus consumption taxation. In particular, Whalley's result holds only in an economy in which there is no productive capital and in which savings involve simply an exchange between those who wish to postpone current consumption and those who wish to raise current consumption.[1] Further, even in a pure exchange economy, Whalley's result does not hold for a comparison of a progressive income tax with either a progressive or a proportional consumption tax. This latter point not only demonstrates the very special nature of Whalley's result, but, since the source of the inefficiency of a progressive income tax in the pure exchange setting applies also to a world in which productive capital exists (and since that inefficiency has received little attention in the current debate over income and consumption taxation), it also reinforces the argument that consumption taxes are preferred to income taxes.

Essentially, Whalley argues that the imposition of an income tax in place of a consumption tax may cause the before-tax interest rate to rise such that the net-of-tax interest rate remains the same as it was under the consumption tax. Consequently, he argues, individuals are no better or worse off under the income tax. It is best to begin the critique of Whalley's analysis with a simple, but general, demonstration of the inefficiency of income taxation relative to consumption taxation. Assume that there is no labor-leisure choice and that, but for the two taxes under consideration, there are no distortions in the economy. Efficiency in the intertemporal market for consumption requires that the price of future consumption be equal to the marginal cost of future consumption. The marginal cost (in terms of foregone current consumption) of \$1 of consumption next year is $1/1+f'$ where f' is the marginal product of capital.[2] The price of future consumption to an individual is $1/1+i_N$ where i_N is the interest rate received by savers net of taxes. Under an income tax system, $i_N<f'$ and, thus, the price of future consumption exceeds its marginal cost, while under a consumption tax, $i_N=f'$, implying that price equals marginal cost. This conclusion is the basis for the argument that, with no labor-leisure choice, an income tax is less efficient than a consumption tax. In spite of Whalley's argument, there is no adjustment in the before-tax interest rate which can remove the income tax induced wedge between the price of future consumption and the marginal cost of future consumption and, thus, no adjustment in the interest rate can obviate the inefficiency of an income tax.[3]

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[1]Though he does make it clear that he is using a two-period consumption-loan model, Whalley does not point out that his conclusion holds only in that setting. He does say that his result "does not appear to hold in an ongoing consumption loan model with overlapping generations" (fn. 4, p. 975). As will be noted below, his result does not hold in such a model for the same reason that it does not hold if there is productive capital.

[2]If there is no productive capital, but the population is growing so that the Samuelson consumption-loan model is applicable, then savings by all generations is still productive. The return to savings is the population growth rate n, and the marginal cost of future consumption is $1/1+n$. If in such an economy n is the gross interest rate, then an income tax will cause inefficiency just as it does in a world in which savings are used to purchase productive capital.

[3]The relationship between the general proposition given above and the type of propositions which Whalley both criticizes and advances is similar to the relationship Milton Friedman pointed out between a "correct" proof of the superiority of income over excise taxes and "alleged" proofs. The alleged proofs discussed by Fried-

If there is no productive capital, then Whalley's result is applicable. In that case, efficiency in the intertemporal consumption market simply requires that borrowers and lenders face the same interest rate.[4] This can be most easily seen using a standard Edgeworth box as shown in Figure 1. Points along the curve *ABC* are equally efficient. Such points will be achieved if borrowers and lenders face the same rate of interest. Clearly, that will be the case if there is no tax. It will also be the case if there is a consumption tax, since interest earnings are effectively not taxed in that situation and interest payments are not tax deductible. Thus, borrowers and lenders face the gross interest rate i_g. Further, if a proportional income tax is imposed and interest payments are tax deductible, then once again borrowers and lenders face the same interest rate and the economy is efficient. That is, lenders receive $i_g(1-\tau)$ after taxes and borrowers pay $i_g(1-\tau)$ net of tax where τ is the income tax rate. This is essentially the proposition demonstrated by Whalley.[5]

If a progressive income tax is used, the conclusion is different. In the two-person case graphed in Figure 1, individual I will pay or receive an interest rate of $i_g(1-\tau_{\mathrm{I}})$ while individual II will pay or receive $i_g(1-\tau_{\mathrm{II}})$, where τ_{I} and τ_{II} are the marginal tax rates for individuals I and II, respectively. In this case, equilibrium will be achieved somewhere along the line *AEC*.[6]

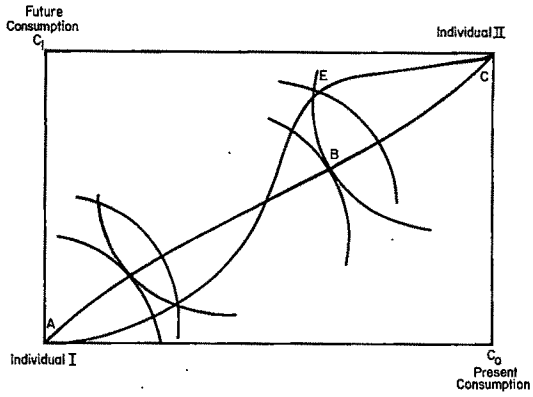

FIGURE 1

Consequently, even in the restrictive setting assumed by Whalley, a progressive income tax is less efficient than a progressive or proportional consumption tax. This conclusion is not altered if one considers a multiperson economy. Efficiency requires that everyone have the same marginal rate of substitution between present and future consumption. Under a progressive income tax system this will not be true, but under a progressive consumption tax system it will.[7]

man assumed that the marginal cost of the taxed good was constant. Whalley correctly objects to demonstrations of the superiority of consumption taxes which treat the gross interest rate as constant. His alternative, however, treats the interest rate in an *ad hoc* manner and does not focus on the gross interest rate as reflecting the marginal cost of future consumption. Friedman's correct proof and the proposition given above are based on determining which taxes cause a divergence between marginal rates of transformation and marginal rates of substitution. As Friedman stresses, such correct proofs are not fully general since they depend crucially upon the absence of other distortions and, in our case, upon the absence of a labor-leisure choice.

[4]More precisely, this requires that there is no productive capital and no population growth so that the Samuelson consumption-loan model is not applicable.

[5]Whalley's precise proposition is a bit less general than the above proposition. He demonstrates that with a particular lump sum redistribution of tax revenues, the interest rate will adjust so that the same equilibrium results from either a consumption or an income tax. In order to demonstrate that the two taxes are equally efficient, all that is necessary is to show that they both result in an equilibrium somewhere along *ABC* in Figure 1. Whether the two taxes result in different equilibria along *ABC* is an equity issue which can be resolved in any desirable way by altering the assumed lump sum redistribution of revenues.

[6]*AEC* and *ABC* intersect at the equilibrium at which, in spite of the progressive tax system, both individuals have the same marginal tax rate. While a graphical analysis has been used here, it might be useful to point out how the effect of progressivity can be seen from Whalley's algebra. His equations 6 (p. 975) and equations 8 (p. 976) are the four equations which assure the equal efficiency of a consumption tax and a proportional income tax. That is, they assure that both individuals face the same interest rate under those two tax systems. If a progressive income tax is used, then equations similar to equations (8) will show the individuals facing different interest rates and, in that case, the equilibrium attained under the consumption tax can not be achieved.

[7]Because under a consumption tax an individual receives and pays the gross interest rate, a progressive consumption tax, unlike a progressive income tax, does not cause individuals to face different interest rates. There is an important implicit assumption underlying

This inefficiency of a progressive income tax also applies in a world in which savings are used to purchase productive capital. In such a setting, not only is the marginal cost of future consumption less than the price of future consumption, but the price is different for all individuals. Most studies of the inefficiency of income versus consumption taxation have assumed proportional taxation (see, for example, Martin Feldstein) and thus have ignored the welfare loss arising from individuals' facing different prices.

the conclusion in the text. It is assumed that both tax systems are perfectly averaged on a lifetime basis. That is, under a progressive income or consumption tax, individual I faces a different tax rate from individual II, but individual I faces the same tax rate in each time period. Likewise, individual II faces the same tax rate in each time period. Under imperfect averaging even a progressive consumption tax may cause intertemporal inefficiency.

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The General Nonneutrality of Income and Consumption Taxes: Reply

By JOHN WHALLEY*

The neutrality argument in my recent note in this *Review* was only intended to illustrate a simple case in which no real effects result with a change from an income tax to a consumption tax (or vice versa). J. Gregory Ballantine is quite correct in suggesting that in practice such a change will not be neutral and that tax reformers need a more complex structure to evaluate the impact of such a tax change.

In its simplest form, the argument presented in my note is that, in a two-person exchange economy, the economy will not be at a point off the contract curve if the tax system does not cause different agents to face different prices. In the pure exchange case, with no progression in tax rates, there is no violation of conditions of exchange efficiency for Pareto optimality under either an income or consumption tax. My concern was with simple one-consumer partial equilibrium diagrams which suggest an intertemporal deadweight loss from the income tax through the "double" taxation of savings, since the result does not necessarily follow from the diagram as usually drawn. Ballantine's comment emphasizes the violation of overall efficiency with the income tax, once production is introduced, and of exchange efficiency, once differences in marginal tax rates across consumers are allowed.

The recognition of the need for a more complex model is to be found in some of the recent numerical general equilibrium tax models which incorporate multiple tax distortions. In the dynamic sequence of equilibria approach used by Don Fullerton, John Shoven, and myself in our general equilibrium model of the *U.S.* economy and tax system, the violation of conditions for general efficiency under the income tax produce a welfare gain from a move to a consumption tax. In our preliminary results a gain occurs whose discounted present value produces an annualized equivalent of around 0.5 percent of *GNP*. In a similar model of the United Kingdom due to J. R. Piggott and myself, where the sequencing approach has not been taken as far, a welfare gain in the region of 1.1 percent of *GNP* is reported from removal of intertemporal distortions in the income tax.

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Keynesian Balance of Payments Models: Comment

By ALAN V. DEARDORFF*

In a recent issue of this *Review*, Edward Kuska stated four propositions which point out flaws in the traditional Keynesian analysis of the balance of payments. The most damning of these are Propositions 2 and 3 which, if they were true, would imply that most of the models in this tradition are, first, internally inconsistent and, second, incomplete in that they fail to assure equilibrium in the bond markets. The remaining propositions (1 and 4) are less devastating, since they expose qualitative properties of the models which Kuska views as unrealistic. Propositions 2 and 3, however, cause him to question the modelling abilities of many of the best known economists in the field, from Meade to Dornbusch, and would be serious indeed if the propositions were valid. It is the purpose of this note to show that they are not.

Kuska's error can be identified quite simply: his budget constraints are incorrectly specified. To see this, consider his first two-economy *IS-LM* model of Section II, in which it is assumed that capital markets are segregated, money stocks are exogenous, and the exchange rate is fixed. He writes the "aggregate budget constraint" for the home economy as follows (his equation (21)):

$$(1) \qquad [Y-C-I+eX^*]+[-eX^*] + \frac{1}{r}[A-H(\ )] + [M-L(Y,r)]=0$$

where Y is income, C is consumption, I is investment, X^* is imports, e is the exchange rate, r is the interest rate, A and M are the stock supplies, and H and L the stock demands, of bonds and money, respectively. A similar equation appears for the foreign economy.

Before I point out the error in this equation, let us note what Kuska does with it. He uses the budget constraints, together with a definition of the balance of payments as the total excess supply of all goods and bonds, to show that the balance of payments equals the excess demand for money, $L-M$.[1] Then, if the money market is assumed to clear, so that $L=M$, it follows that the balance of payments is zero and, in the absence of capital flows, that trade is balanced also. From this he gets his Proposition 2: that a model which assumes money-market equilibrium, together with a separate specification of nonzero balance of payments, is inconsistent.

Now it is unclear from the context whether equation (1) above is intended to refer only to the private sector, or to the whole economy including its government and central bank. But the equation is incorrect in either case, since it fails to allow for the intervention in the exchange market that must occur if the exchange rate is fixed, and for the need to finance that intervention by changing the stocks of money and/or bonds.

Consider first the budget constraint for the economy as a whole, including its government and central bank. This should require that the values of excess supplies of all goods sum to zero. The left side of equation (1) includes, as the four bracketed expressions, the excess supplies of domestic goods, foreign goods, bonds, and money. But it does not include the excess supply of foreign exchange that the government contributes to the exchange market when it intervenes to peg the exchange rate. This

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[1]This identification of the balance of payments with the excess demand for money is a familiar part of the monetary approach to the balance of payments, though what is meant by the excess demand for money is often unclear. One author, Norman Miller, derives precisely the same result as Kuska using the same misspecified budget constraint. See fn. 3 below.

intervention must equal the negative of the balance of payments, B, if the exchange market is to be in equilibrium.[2] Thus the budget constraint for the economy as a whole should be the following:

$$(2)\qquad [Y-C-I+eX^*]+[-eX^*]+\frac{1}{r}[A-H(\ )]+[M-L(Y,r)]+[-B]=0$$

From this formulation of the budget constraint it is not possible to use Kuska's technique to derive that the balance of payments must be zero. On the contrary, any value of B is admissible, zero or nonzero, and it is quite appropriate to include in the model a separate equation for determining it.

By omitting the excess supply of foreign exchange from the budget constraint, Kuska effectively assumes that no intervention on the exchange market takes place. His conclusion that the balance of payments must be zero is then not surprising, but it is a result of his own implicit assumption rather than of the models he attempts to criticize. It is also to be expected that a model with this assumption will be overdetermined. Any government which attempts to fix the exchange rate without also intervening in the market to bring this about is bound to run into difficulty.[3]

If we interpret (1) as referring only to the private sector, our approach must be somewhat different but the result is the same. Now, since the private sector does not hold foreign exchange, it is correct to include in the budget constraint only the excess supplies of goods, money and bonds. However, the expressions representing these excess supplies in equation (1) are incorrect if they apply only to the private sector. The private sector budget constraint should require that income be sufficient to finance the flow demand for goods plus the net *accumulation* over the period of money and bonds. The expressions $(1/r)[A-H]$ and $[M-L]$ represent such accumulation only if the supplies forthcoming from the government, A and M, are constant over the period. But if the government is intervening in the foreign exchange market, then it must finance that intervention by varying, over time, the quantities of money and/or bonds outstanding. Thus if the end of period supplies, A and M, are to be used in the private sector budget constraint, an adjustment must be made to reflect the financing of government intervention in the foreign exchange market.

Properly specified, then, the private sector budget constraint should be as follows:

$$(3)\qquad [Y-C-I+eX^*]+[-eX^*]+\frac{1}{r}[A_{-1}-H(\ )]+[M_{-1}-L(Y,r)]=0$$

where unsubscripted variables represent either flows over the current period or stocks at the end of the period, and A_{-1} and M_{-1} are the stocks held at the beginning of the period. Again, the correctly specified budget constraint does not permit derivation of Kuska's result that the balance of payments must be identically zero.

To see the relationship between (3) and the other budget constraints mentioned earlier, note what happens if we consider the budget constraint of the government *cum* central bank. Assuming for simplicity that the government neither taxes nor buys goods, its constraint is simply that its purchases of foreign exchange equal in value its issuance of new money and bonds:

$$(4)\qquad B=[M-M_{-1}]+\frac{1}{r}[A-A_{-1}]$$

It is easily seen that (3) and (4) together imply (2) rather than (1). And indeed (2) can

[2]It is assumed here that intervention is done by the domestic government or central bank. Were a foreign agency to intervene instead by acquiring domestic money or bonds, the supplies of these stocks available to domestic residents would be altered as a result. Equation (2) below would still be obtained, though for a slightly different reason.

[3]Miller, in his equation (3), made the same mistake of omitting the excess supply of foreign exchange from the budget constraint.

be viewed as representing the budget constraint of the private sector, with the term $[-B]$ serving as an adjustment to the supplies of money and bonds rather than as a separate excess supply of a good.

Let us turn finally to Kuska's third proposition that conventional models fail to assure equilibrium in both bond markets. This is based on the seemingly unexceptionable observation that such models omit both bond markets, whereas only one market can be legitimately excluded by application of Walras' Law. In fact, however, such models typically include the foreign exchange market, as well as the markets for goods and money. As we will see, the foreign exchange market is not an independent market in a two-country model, and its inclusion permits us to omit a second market.

To see this, let us write down the equilibrium conditions for the goods, money, and bond markets in both countries, plus the market for foreign exchange. We continue to assume, for simplicity, that only goods (and international reserves) move internationally.

$$Y=C+I+X-eX^* \tag{5}$$

$$M=L \tag{6}$$

$$A=H \tag{7}$$

$$Y^*=C^*+I^*+X^*-(1/e)X \tag{8}$$

$$M^*=L^* \tag{9}$$

$$A^*=H^* \tag{10}$$

$$B=X-eX^* \tag{11}$$

Note that while (11) may be regarded as simply the definition of the balance of payments (which equals the balance of trade since there are no capital flows), it is also the equation for equilibrium in the foreign exchange market if we regard B as measuring the government's intervention there. For it says that the net supply of foreign exchange forthcoming from the private sector, $X-eX^*$, must equal the government's demand for foreign exchange, B.[4]

It is now an easy matter to show that the correct domestic-economy budget constraint (2) implies that equations (5), (6), (7), and (11) are interdependent.[5] In particular, if the exchange market clears together with the markets for domestic goods and money, then equation (7) must hold and the domestic bond market clears as well. By similar reasoning, the foreign-economy budget constraint—which is analogous to (2) in all respects—can be used to show the interdependence of equations (8), (9), (10), and (11). Thus equilibrium in the foreign bond market is also assured by equilibrium in the markets for foreign goods and money plus foreign exchange.

Kuska's contention, then, that equilibrium in bond markets is not assured in conventional models is incorrect. His mistake was a natural one since, on the face of it, it does appear absurd to leave out two markets and still expect them to clear. But the foreign exchange market plays a special role in the international economy, balancing the international transactions in all other markets. It is this special role that makes it dangerous to adopt uncritically the arguments that would be valid in a closed-economy general equilibrium system where there is only one form of money.[6]

[4]I have defined B as the balance of payments of the domestic country in units of its currency. The foreign country's balance of payments can be defined similarly as $B^*=(1/e)B$. For simplicity we may think of all intervention as using the medium of an international reserve asset, such as gold, which the surplus country buys, and the deficit country sells, whenever there is a payments imbalance. If governments were to deal in and accumulate each other's money or bonds directly, then intervention would affect demands in these markets as well as supplies. The analysis would be more complicated but the result would not be changed.

[5]To see this, note for example that when (5), (6), and (7) are substituted into (2), the result is identical to (11).

[6]Indeed one could argue that the exchange market does not belong in the system at all. Once the goods, money, and bonds of both countries are included, foreign exchange itself does not exist as a separate commodity. If it were left out, then the markets for the other six commodities would be handled normally with only one of their markets omitted by Walras' Law. But since

Before concluding, it should be mentioned that this defense of the internal *consistency* of conventional Keynesian models is not meant to imply that they are also the most realistic or useful models of international behavior. Kuska's first proposition, though hardly new, is valid,[7] and Keynesian models can be, and often have been, faulted on other grounds as well. But little progress can be made toward improving them if their internal structure is misunderstood. It is to be hoped that this note will help to correct that misunderstanding.

the exchange market equation is implied by the others, there is nothing wrong with including it instead of one of them, and for many the resulting symmetric formulation has more intuitive appeal.

[7]His first proposition is a variant of one of the pitfalls pointed out by William Brainard and James Tobin a decade ago, and of course the role of wealth in Keynesian models has been a topic of discussion for much longer than that.

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Keynesian Balance of Payments Models: Comment

By NORMAN C. MILLER*

In a recent article Edward Kuska alleges that Keynesian models of the balance of payments (*KBP*) are almost totally inadequate. The details of his indictments are explained below, but the upshot of the arguments is that when a monetary approach to the balance of payments (*MBP*) is taken, it appears as though *KBP* models involve logical contradictions, have structures that are not in accord with what is dictated by Walras' Law, and are not useful for longer-run analysis. It is shown here that Kuska and the *MBP* use a different definition of the *ex ante* balance of payments than is used in the *KBP* models. Also, Kuska uses a definition of the excess supply of money that differs from that used in some *KBP* models. When these differences are taken into account, the *KBP* models are not subject to the above criticisms.

The difference in the (usually implicit) definitions of the *ex ante* balance of payments is of extreme importance because it pinpoints a fundamental difference between *MBP* and *KBP* models. The *MBP* definition assumes that all markets but the money market are in equilibrium, that is, the commodity and bond markets always clear. This implies that home and foreign residents always buy and sell internationally all that they optimally desire, and that the balance of payments is always equal to the magnitude of the money market disequilibrium. In contrast, the *KBP* models assume that the commodity and money markets clear in an *ex ante* sense. Furthermore, *KBP* models implicitly assume that bond markets do not clear, and, consequently, the *ex ante* balance of payments is always equal to the magnitude of the bond market disequilibrium. For example, if home residents desire to sell more bonds to foreigners than they actually do sell, then a home payments deficit arises.

In addition, both *KBP* and *MBP* models utilize two different definitions of the excess supply of money. In some models the current period's induced flow of international reserves is included in the definition, and in other cases it is excluded. Kuska implicitly uses the second approach, and those *KBP* models that use the first approach are free of Kuska's criticisms.

I

Kuska uses a discrete time period analysis to develop four propositions concerning *KBP* models. The home economy's budget constraint is given by[1]

$$\text{(K21)} \qquad E_C + E_A + E_M \equiv 0,$$

where

$$E_C \equiv Y - C(Y, r) - I(r)$$

$$E_A \equiv A - H(\ )$$

$$E_M \equiv M - L(Y, r)$$

All variables are in real terms and Y, C, I, and r are, respectively, income, consumption, investment, and the interest rate. A and H are bond supply and demand, while M and L are the supply and demand for money. In addition, the *ex ante* home balance of payments, B, is defined along *MBP* lines.[2]

$$\text{(K23)} \qquad B \equiv E_C + E_A$$

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[1]The notation here differs from Kuska's in two ways. First, he defines A and H as the quantity of bonds supplied and demanded, and their nominal (and real) values are found by multiplying A and H by bond prices, $1/r$. Second, Kuska uses the E_i term only with regard to the bond market, and in his paper E_A is the excess *demand* for bonds.

[2]Kuska does not use E_C and E_A, but rather writes (K23) as $B = (Y - C - I) + (A - H)$.

PROPOSITION 1: *The absence of any wealth variables in the demand functions for C and L implies an unrealistic bond demand function wherein changes in money or in the supply of bonds lead to equal changes in bond demand. To see this, use* (K21) *and the definitions of the* E_i *to get*

$$\text{(K8)} \qquad H(\ ) \equiv -[L(Y,r)+C(Y,r)+I(r)-Y]+A+M \equiv \bar{H}(Y,r)+A+M$$

This criticism is correct and will not be discussed further, except to point out that many *MBP* models also use similar demand functions.[3]

PROPOSITION 2: *Most KBP models involve a logical contradiction since the money market is assumed to clear,* $E_M=0$, *but the balance of payments, B, is allowed to be nonzero. The contradiction follows from the fact that* (K21) *and* (K23) *together yield*

$$\text{(K25)} \qquad B \equiv -E_M$$

The *ex ante* balance of payments must always equal minus the excess supply of money.

PROPOSITION 3: *In two-country KBP models, Walras' Law is invoked to drop both the home and foreign bond market equations. However, there is only one redundant equation and nothing provides for the suppression of the second equation; when two are dropped it implies that neither market may be in equilibrium, and "... this fact alone should have been indication enough to theorists... that something was wrong"* (Kuska, p. 662).

PROPOSITION 4: *Some KBP models avoid the logical contradiction suggested by Proposition 2 by assuming that any disequilibrium in the home money market is matched by an equal in magnitude but opposite in sign disequilibrium in the foreign money market, and that these money market imbalances are equal to the balance of payments. Kuska claims that such models are not acceptable for balance of payments analysis because they imply a zero B in the second and each succeeding time period.*

Algebraically, this is represented by

$$\text{(K39)} \qquad E_M \equiv -E_M^* \equiv -B$$

where E_M^* = the foreign excess supply of money. Any disequilibrium in the money markets is eliminated in the first period by the flow of international reserves; thus, allegedly both money markets are in equilibrium and B is zero in every period thereafter.[4]

II

In order to explore Kuska's Propositions and the adequacy of *KBP* models it is necessary to expand Kuska's framework. The Appendix gives all details. The framework is for a two-country fixed exchange rate world wherein each country has an Exchange Stabilization Fund (*ESF*) that buys and sells international reserves, R, that flow between the countries when the balance of payments is nonzero.[5] Each country's combined central bank plus treasury (hereafter called the government) automatically buys or sells R from its *ESF*, and fully monetizes any changes in international reserves. However, each government may sterilize some or all of the effects of the change in R on its monetary base.

This section uses excess supply terms that by definition include only *ex ante* or autonomous demands and supplies. More specifically, the excess supply of money excludes any current period induced changes in money via current period flows of international reserves or via sterilization activities. This approach is implicit in Kuska's paper as well

[3]See, for example, Harry Johnson and the empirical studies in Jacob Frenkel and Johnson.

[4]Kuska points out that this conclusion also requires that there be no wealth effect in the nonsuppressed demand functions.

[5]R is gold, *SDR*'s, or some other international reserve asset; it is not the currency of either country. The analysis assumes that each country's money is held exclusively by the private sector of that country, and that no R is held privately.

as in many *MBP* models, and it is consistent with those *KBP* models that have an exogenous money supply.

The sum of the budget constraints for the home private sector and home government gives

$$(1) \qquad E_C + E_A + E_M \equiv 0$$

where the E_i terms are similar (but not identical) to the E_i in Kuska's equation (K21) above.[6] In a closed economy each E_i is the total market excess supply. However, in an open economy the market excess supplies, X_i, are equal to the E_i adjusted for *ex ante* international transactions. Algebraically,[7]

$$(2) \quad X_C \equiv E_C - BT,\ X_A \equiv E_A - KF,\ X_M \equiv E_M,$$

where the balance of trade BT is defined as the foreign demand for imports minus the home demand for imports, and the net capital flow KF is defined as the change in foreign demand for domestic bonds minus the change in home demand for foreign bonds. Consequently,

$$(3a) \qquad X_C + X_A + X_M \equiv E_C + E_A + E_M - BT - KF \equiv -BP$$

where BP is the demand determined *ex ante* home balance of payments. In the foreign country we have a similar identity.

$$(3b) \quad X_C^* + X_A^* + X_M^* \equiv -BP^* \equiv BP$$

III

A typical two country *KBP* model contains the equations

$$(4a) \quad X_C = 0,\ X_M = 0,\ BP \equiv BT + KF$$

$$(4b) \quad X_C^* = 0,\ X_M^* = 0$$

with the KF term omitted in many models. Small country *KBP* models use only equations (4a). It is clear from (3a) and (4a) that Kuska's Proposition 2 is incorrect. The balance of payments can be nonzero even though the money market clears in an *ex ante* sense, if the bond market is out of equilibrium, that is, $X_A = -BP$, and this is what *KBP* models implicitly assume.

The basic issue involves a difference between the implicit definition of the *ex ante* balance of payments used by Kuska (and other *MBP* advocates) versus that used implicitly in *KBP* models. In summary form: (K23) *MBP* Definition is $B \equiv E_C + E_A$; and the *KBP* definition is

$$(5) \qquad BP \equiv BT + KF$$

The *MBP* definition of the *ex ante* balance of payments implicitly assumes that all markets except the money market are in equilibrium. The logic is as follows. First, E_C and E_A are the excess of home supply over home demand in the commodity and bond markets. If E_C is also defined as the *ex ante* trade balance, and E_A is defined as the *ex ante* net capital flow (as is implicit in *MBP* models), then obviously these *ex ante* net international transactions exactly offset each domestic E_i, and both markets are always in equilibrium. Alternatively and equivalently, if a model contains *ex ante* trade balance and capital flow equations that are defined to be demand determined (as in all *KBP* models and some *MBP* models including Kuska's), then from (3a) it is clear that $X_M = -BP$ only when $X_C + X_A = 0$, as will be true when the commodity and bond markets are in equilibrium.[8] In such a case the Keynesian demand-determined balance of payments BP will equal the monetary approach balance of payments, B.

In sum, the *MBP* and Kuska's analysis implicitly assume that the commodity and bond markets are always in equilibrium. A balance of payments deficit arises only because people have excess cash balances and attempt to draw them down. This is equiva-

[6]See the Appendix for all definitions.

[7]See the Appendix for the derivation of these identities.

[8]Miller explores the possibility that neither X_C nor X_A may be zero, but their sum is zero.

lent to a budget deficit by an economic unit that is able to buy and sell all that it plans, but which begins the time period with more money than is optimal for it.

Contrastingly, in *KBP* models a payments deficit arises because home residents do not sell all the bonds that they plan. That is, if $X_A = -BP$ then a payments deficit implies $X_A > 0$. This is equivalent to the situation where an economic unit is happy with its initial money balances, but it incurs a budget deficit because of the inability to sell all that it plans. In a monetary world, the economic unit will be forced to draw down its money balances to pay for its unplanned budget deficit, but this outflow of money is an induced financing item, and not a result of an initial excess supply of money. Similarly in *KBP* models, each deficit country is forced to draw down its level of international reserves, but this is simply an induced financing phenomenon that in no way implies an initial *ex ante* excess supply of money within the economy.[9]

Kuska's Proposition 3 is also incorrect. There is nothing wrong with two-country *KBP* models that omit both bond market equations. Any model that contains the equations in (4a) and (4b), and that does not constrain the balance of payments to zero, is implicitly assuming that neither bond market clears, since from (3a) and (3b) it follows that $X_A = -BP = -X_A^*$. There would be something wrong with any such model if it did not omit both bond market equilibrium conditions.

Finally, Kuska's Proposition 4 is also incorrect. Suppose that in the first time period we have $X_C = 0 = X_C^*$, and $X_M = 10 = -BP = -X_M^*$. From (3a) and (3b) these assumptions imply $X_A = 0 = X_A^*$; both commodity and both bond markets are in equilibrium, and the home (foreign) country has an excess supply (demand) of money that is equal to its balance of payments deficit (surplus) of 10. If both countries completely sterilize the effects of the first period's flow of money, then in the second period $X_M = 10 = -BP = -X_M^*$ again.[10] The payments deficit continues. Alternatively, if no sterilization occurs, then in the second period $X_M = X_M^* = 0$, provided we follow the typical *KBP* assumption of ignoring any wealth effects in the money demand functions.[11] Also, with no wealth effects in the commodity demand functions, we now have $X_C = 0 = X_C^*$ in the second period. Consequently, from (3a) and (3b) we conclude that in the second period $X_A = -BP = -X_A^*$. Furthermore, if each country's demand for its own bonds has a unitary wealth effect (which is implicit in the *KBP* models), then neither bond market will clear in an *ex ante* sense in the second period. This occurs, for example, because the loss of 10 units of home money leads to a decrease in the home demand for home bonds by 10; since the supply of home bonds is unchanged (by assumption) the result is an excess supply of home bonds of 10 in the second period, and a home payments deficit of 10.[12] Similarly, since the foreign country gains reserves, its bond demand increases, and $X_A^* = -BP^* = -10$.

IV

Finally, let us consider those *KBP* models that explicitly or implicitly include the current period's induced flow of international reserves in the definition of the excess supply of money. Define such money market excess supplies as $\bar{X}_M$ and $\bar{X}_M^*$. It is shown in the Appendix that the sum of the budget constraints for the private sector, government

[9]In disequilibrium macroeconomics terminology the *ex ante* primary excess supply of money is zero, but when spillover effects are taken into account, then the excess supply of money is nonzero.

[10]This conclusion requires the *KBP* (implicit) assumption of a unitary coefficient for the wealth variable in the home demand for domestic bonds. With this assumption, the sterilization activities affect bond demand and supply equally so that both bond markets remain in equilibrium.

[11]All of this assumes that the interest rates are called out at the beginning of the second time period are the same as those that prevailed in the first time period.

[12]It appears as though Kuska's Proposition 4 would be correct if: (a) X_M is defined as in Section II above; (b) no sterilization activities occur; and (c) home and foreign investors have identical tastes, i.e., the flow of R has no net influence on the demands for either country's bonds. However, I know of no *KBP* models that make such assumptions.

sector, and *ESF* in each country gives

$$(6)\quad \bar{X}_C+\bar{X}_A+\bar{X}_M=0;\ \bar{X}_C^*+\bar{X}_A^*+\bar{X}_M^*=0$$

These excess supplies include both *ex ante* autonomous demands and supplies, and *ex post* induced items such as the flow of international reserves and the effects of sterilization activities on each $\bar{X}_i$ or $\bar{X}_i^*$.[13]

The omission of any balance of payments terms in (6) implies that models which specify excess supply functions in this manner have no necessary relationship between the *ex ante* balance of payments and the state of the commodity, bond, and/or money markets. The balance of payments must be defined by a separate equation such as $BP=BT+KF$, which, so to speak, "comes out of left field."

Because of (6) there is no relationship between the state of money markets and the balance of payments, that is, $\bar{X}_M=0=\bar{X}_M^*$ does not preclude a nonzero value for the balance of payments. In other words, Kuska's Proposition 2 is incorrect here. Furthermore, any *KBP* model of the form

$$(7)\quad \bar{X}_C=0,\ \bar{X}_C^*=0,\ \bar{X}_M=0,\ \bar{X}_M^*=0$$

and $$BP=BT+KF,$$

must omit both bond market equilibrium equations since (6) and (7) imply that both bond markets clear. Consequently, Kuska's Proposition 3 is also incorrect within this framework. Finally, there is no reason why any model that requires

$$(8)\qquad \bar{X}_M=-\bar{X}_M^*=-BP$$

should automatically generate a payments equilibrium after one time period. The $\bar{X}_M$ and $\bar{X}_M^*$ terms include the current period's flow of international reserves within them; hence, if the current BP and $\bar{X}_M$ are not zero, there is no mechanism that will make them zero in the second period.

[13]Such a model is $X_C=0$, $D+R-L=0$, and $R-R_o \equiv BT+KF$, as Kuska describes on page 667.

V

In summary, the *KBP* models are not subject to the last three of Kuska's four propositions. Kuska's analysis and his conclusions about the structure of macro models for an open economy are correct, given his assumptions. However, the *KBP* models utilize a different definition of the balance of payments and, in some cases, also a different definition of the excess supply of money.

Kuska's *ex ante* balance of payments concept is implicit in the *MBP* literature, and it relates to what is desired or planned by the residents of any one country; for example, the home country *ex ante* trade balance is the excess of home supply over home demand for commodities. Many *MBP* models (including Kuska's) also contain demand functions for exports, imports, and capital flows; consequently such models implicitly assume that all markets but the money market are always in equilibrium, and the balance of payments equals the disequilibrium in the money market.

The Keynesian *ex ante* balance of payments is defined as foreign demand for home commodities and bonds minus home demand for foreign commodities and bonds. The *KBP* models implicitly assume that the bond markets do not clear, and, consequently, the balance of payments is equal to the disequilibrium in the bond markets. Such *KBP* models are not subject to Kuska's last three criticisms.

Finally, Kuska's implicit definition of the excess supply of money differs from that used in some *KBP* models, which define the excess supply of money to include the current period's induced flow of international reserves. In such models there is no relationship between the *ex ante* balance of payments (regardless of its definition), and the state of the money market, or any other market. Therefore, such *KBP* models are also not guilty of Kuska's last three indictments.

APPENDIX

The definitions used here are the same as in the text, with the following additions: G,

Tx = government demand for commodities, and net taxes; $H = H_d + (H_{f_o} + \Delta H_f)$ ... total home demand for bonds equals home demand for domestic bonds, H_d, plus the sum of the initial, H_{f_o}, and change in, ΔH_f, home demand for foreign bonds; $H^* = H_f^* + (H_{d_o}^* + \Delta H_d^*)$ ... total foreign demand for bonds equals foreign demand for foreign bonds, H_f^*, plus the sum of the initial and the change in foreign demand for domestic bonds; $M_o = D_o + R_o$ ... the money supply is the sum of the domestic assets, D_o, and the international reserves, R_o, held by the central bank; ΔR = the change in international reserves held by the home government, ... but not the home *ESF*; $BT = Im^* - Im$ ... the home *ex ante* balance of trade is foreign demand for imports, I_m^*, minus home demand for imports; $KF = \Delta H_d^* - \Delta H_f$ = the home country's *ex ante* capital account balance; and finally, $BP = BT + KF = -BP^*$ = the home country's *ex ante* balance of payments, which is minus the foreign country's balance of payments.

The budget constraints in the home economy for the private sector, government sector, and *ESF* are, respectively:

$$\text{(A1)} \qquad (Y - Tx) + (D_o + R_o) + \left[(A_0 - H_{d_o}) + H_{f_o}\right] \equiv C + I + L + H$$

$$\text{(A2)} \qquad Tx + \Delta D + \Delta R + \Delta A \equiv G + \Delta R$$

$$\text{(A3)} \qquad \Delta R \equiv BT + KF$$

where $\Delta D = \Delta \bar{D} - s\Delta R$ ... the change in D has autonomous, $\Delta \bar{D}$, and induced, $s\Delta R$, sterilization components; s = the sterilization coefficient; and $\Delta A = \Delta \bar{A} + s\Delta R$ ... the change in A has autonomous and induced sterilization components.

In (A2) the ΔR term is both a use for funds (when ΔR is purchased from the *ESF*), and a source of funds (when ΔR is monetized). In (A3) the ΔR is a source of funds for the *ESF* since a $\Delta R > 0$ represents a build up of R by the government as a result of sales of R by the *ESF*. The right-hand side of (A3) reflects the fact that the *ESF* must use home currency to buy R in an amount equal to $BT + KF$.

If $s = 0$ then the sum of (A1) and (A2) gives (1) in the text, where $E_C \equiv (Y - C - I - G)$; $E_A \equiv (A_o + \Delta A_o) + (H_{f_o} - H_{d_o}^*) - H$; and $E_M \equiv D_o + R_o + \Delta D - L$. Furthermore, if $s = 0$ then the sum of (A1), (A2), and (A3) gives (3a) in the text, where $X_C \equiv (Y - C - I - G - BT) \equiv E_C - BT$; $X_A \equiv (A_o + \Delta \bar{A}) - H_d - H_d^* \equiv (A_o + \Delta \bar{A}) - (H - H_{f_o} - \Delta H_f) - (H_{d_o}^* + \Delta H_d^*) \equiv E_A - KF$; and $X_M \equiv D_o + R_o + \Delta \bar{D} - L \equiv E_M$.

With sterilization activities, that is, $s > 0$, the sum of (A1), (A2), and (A3) yields

$$\text{(A4)} \qquad X_C + (X_A + s\Delta R) + (X_M + (1 - s)\Delta R) \equiv -\Delta R + \Delta R$$

or

$$\text{(A5)} \qquad \bar{X}_C + \bar{X}_A + \bar{X}_M \equiv 0$$

When the induced international reserve flows and sterilizaton terms are not included in the definitions of the excess supplies, then (A4) reduces to (3a) in the text. If these induced items are included in the definitions of the excess supplies (as in Section IV in the text), then we get (A5), which is the home country's identity in (6).

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Keynesian Balance of Payments Models: Commen

By WILLEM H. BUITER AND JONATHAN EATON*

In a recent paper, Edward Kuska delivers a sweeping indictment of Keynesian balance of payments theory: "...almost all of the models of the Keynesian balance-of-payments literature suffer from internal contradictions and deficiencies which make them unsuitable for balance-of-payments theory" (p. 659). His critique of Keynesian balance of payments theory is expressed in four propositions (p. 664). Propositions 2 and 4 are incorrect. Proposition 3 is correct except in a world without capital mobility, which was the case considered by Kuska. Proposition 1 is correct (and familiar) and has been incorporated into Keynesian models of the balance of payments without changing any of their essential features or policy implications. Propositions 2 and 4 are based on a fundamental stock-flow confusion while Proposition 3 reflects a misspecification of budget constraints or balance sheet constraints in different countries.

Section I provides a brief general discussion of asset-market equilibrium and Walras' Law that brings out the fundamental error in Kuska's analysis. The results cited in this section are not new, but have not before been brought together in a concise and simple framework. Section II develops a two-country model akin to Kuska's that combines asset-market equilibrium with balance of payments disequilibrium and derives its most important short- and long-run properties. This model is specified to satisfy the "adding-up constraints" emphasized by William Brainard and James Tobin and Tobin, thus avoiding the pitfall referred to in Proposition 1. It should be noted that practically no one has violated the adding-up requirement since the publication of Brainard and Tobin's 1968 paper. One implication of the model is that international trade in financial assets prevents the monetary authority in one of the two countries from maintaining even short-term control over its own domestic money stock. This result is independent of the degree of substitutability between the bonds of the two countries. All that is required is that the private sector in each country can hold foreign bonds and that bonds are traded in perfect markets. The Keynesian models so summarily dismissed by Kuska are special cases of our consistent stock-flow model.[1]

We do not argue that the simple Keynesian models which Kuska attacks, those of James Meade, Robert Mundell, J. M. Fleming, Egon Sohmen, and S. C. Tsiang, for instance, are free of serious deficiencies: they focus almost exclusively on the short run; commodity and factor prices are fixed and capacity constraints ignored; the relationship between income-expenditure equilibrium and the flow of funds is often neglected. Nevertheless, these models are internally consistent. Furthermore, much recent Keynesian macroeconomic and balance of payments theory is aimed at correcting these deficiencies. William Branson (1976a, b), Peter Kenen, Stephen Turnovsky (1976), Buiter (1978), and Gary Smith and William Starnes, for example, explicitly incorporate long-run effects of financial asset flows and limited price flexibility into Keynesian open-economy models.[2]

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[1]In a longer version of this paper (1979) we illustrate this with a popular model of the balance of payments in a Keynesian economy which consistently combines balance of payments disequilibrium with asset-market equilibrium.

[2]The role of exchange rate expectations and the forward discount under a flexible exchange rate regime was never properly analysed in these models. It is here that the monetary or asset-market approach has made its most significant contributions, for example, Jacob Frenkel, Michael Mussa, Rudiger Dornbusch (1976), J. F. O. Bilson, and Eaton.

While Kuska directs his attack at "Keynesian" models of the balance of payments, his Propositions 2 and 4, if they were true, would apply equally to a number of authors adopting the "monetary approach" to the balance of payments. Jacob Frenkel and Carlos Rodriguez, for instance, in an article which Kuska cites among others as "largely free of [these] criticisms" (p. 659) do *in fact* develop a monetary model of the balance of payments which incorporates simultaneous money-market equilibrium and balance of payments disequilibrium. Rudiger Dornbusch (1975) provides another example of a model adopting the "monetary approach" which combines continuous asset-market equilibrium with a nonzero international payments balance. Our absolution of Keynesian balance of payments models thus applies equally to these (nonindicted) monetary models.

I. On Asset Market Equilibrium and Walras' Law

A number of recent papers on asset-market equilibrium in discrete and continuous time models have illuminated the distinction between two different notions of asset-market equilibrium: beginning-of-period and end-of-period equilibrium (Josef May, Sheetal Chand, Duncan Foley, Buiter (1979, 1980), Buiter and Geoffrey Woglom, Turnovsky (1977), Turnovsky and Edwin Burmeister). The distinction between the two is most easily demonstrated in discrete time.

Let $S^i(t)$ denote the stock of good i extant at the beginning of period t or, equivalently, the stock carried over from period $t-1$. The term $Q^i(t)$ denotes the planned production (issue or inflow) of good i and $C^i(t)$ the planned consumption (liquidation or outflow) of commodity i during period t. Let $p^i(t)$ denote the price of good i in period t. Finally, let $D^i(t_1, t_2)$ be the demand for good i, planned and expressed in the market at time t_1, to be held at time t_2.[3] Thus $D^i(t, t+1)$ denotes the demand for commodity i in period t to be carried over to the beginning of period $t+1$. We refer to this magnitude as *end-of-period* demand. Total market demand for good i during period t consists of demand for current consumption $C^i(t)$ plus end-of-period demand. Total market supply consists of initial stocks, $S^i(t)$ and period t production, $Q^i(t)$.

Thus,

$$(1)\quad S^i(t)+Q^i(t)=C^i(t)+D^i(t,t+1)$$

is a statement that supply equals demand for commodity i during period t.[4] When markets clear, $\Delta S^i(t) \equiv S^i(t+1)-S^i(t)=Q^i(t)-C^i(t)=D^i(t,t+1)-S^i(t)$. *Walras' Law* holds that the sum of the excess demand for all goods, real and financial, valued at $p^i(t)$, equals zero, that is, that

$$(2)\quad \sum_{i=1}^{n} p^i(t)\left[D^i(t,t+1)+C^i(t)-S^i(t)-Q^i(t)\right]\equiv 0$$

where n denotes the total number of goods. If condition (1) obtains for $n-1$ goods, then it must obtain for all n. One market equilibrium condition can be suppressed.

Implicit in Kuska's Propositions 2 and 4 is a notion of money-market equilibrium equating end-of-period demand $D^i(t, t+1)$, to beginning-of-period supply $S^i(t)$, rather than end-of-period supply, that is,

$$(1')\quad D^i(t,t+1)=S^i(t)$$

replaces (1). Clearly (1′) is correct only if $Q^i(t)=C^i(t)$. This will hold for all t only in stationary states when asset supplies are constant. A balance of payments disequilibrium implies that asset supplies are changing: the deficit country loses assets to the surplus country. Condition (1), the proper notion of end-of-period asset-market equilibrium, is perfectly consistent with $C^i(t)\neq Q^i(t)$. From the end-of-period equilibrium point of view, Kuska's error arises in his equations (21) and

[3]More generally, we could allow the time at which plans are made to differ from the time at which they are expressed in the market. Buiter (1980) discusses this distinction. See also footnotes 7 and 8.

[4]Equilibrium condition (1) applies equally to nondurables, in which case equilibrium implies $Q^i(t)=C^i(t)$, and to "old masters," where it implies $S^i(t)=D^i(t,t+1)$ (ignoring destruction).

(22) where he imposes an erroneous notion of Walras' Law based on the market equilibrium condition (1'). We return to this point in Section II.

The alternative notion of asset-market equilibrium is that of beginning-of-period equilibrium: initial stock supply equals demand for the stock at the same instant or

$$(3) \qquad D^i(t,t)=S^i(t).$$

Beginning-of-period demands are related by the balance sheet constraint which states that any one of the asset-market equilibrium conditions can be suppressed,

$$(4) \qquad \sum_{i=1}^{m} p^i(t)\left[D^i(t,t)-S^i(t)\right]\equiv 0,$$

which is independent of the flows in period t. The number of durable commodities is $m \leq n$. Goods are ordered such that the first m are durables. Market flow equilibrium for nondurables is given by

$$(5) \qquad C^j(t)=Q^j(t); j=m+1,\ldots,n.$$

Kuska's equations (21) and (22) are equally erroneous from the beginning-of-period viewpoint of equilibrium since they sum instantaneous stock excess demands and flow excess demands at current market prices. (Note that with durable capital and investment spending I, the output market equilibrium condition $C+I=Y$ is an end-of-period equilibrium condition. See Buiter (1979) and Turnovsky (1977) for a further discussion).[5]

In a continuous-time formulation of both beginning-of-period and end-of-period equilibrium, instantaneous rates of flow of production and consumption at any instant do not affect stocks at that instant. Denote $Q^i(t)=q^i(t)\Delta t$ and $C^i(t)=c^i(t)\Delta t$ where Δt is the length of the unit period. As Δt goes to zero, both (1) and (3) reduce to

$$(6) \qquad D^i(t,t)=S^i(t); i=1,\ldots,m.$$

Instantaneous asset-stock demands are related by the balance sheet constraint:

$$(7) \qquad \sum_{i=1}^{m} p^i(t)\left[D^i(t,t)-S^i(t)\right]\equiv 0.$$

Again, any one of the *asset*-market equilibrium conditions can be omitted. Market equilibrium for nondurables, for which $D^i(t,t)\equiv S^i(t)\equiv 0$, is given by

$$(8) \qquad c^j(t)=q^j(t); j=m+1,\ldots,n.$$

When markets clear, $\dot{S}^i(t)=q^i(t)-c^i(t)$, $i=1,\ldots,m$.

In the continuous-time formulation the instantaneous rates of flow in (8) and the stocks in (7) are not even dimensionally commensurate. They cannot be added together into a single Walras' Law for this reason alone.[6,7]

[5]A consistent planning requirement or "psychological" (as opposed to market) flow budget constraint relates stocks and flows in the beginning-of-period formulation. Let $D^i(t_1,t_2,t_3)$ denote the demand for good i, planned at time t_1, to be expressed in the market at time t_2, to be held at time t_3; $\hat{p}^i(t,t+1)$ denotes the price of good i expected, in period t, to prevail during period $t+1$. Consistent planning requires

$$\sum_{j=1}^{m} \hat{p}^j(t,t+1)\left[D^j(t,t+1,t+1)-D^j(t,t,t)+C^j(t)-Q^j(t)\right]+\sum_{i=m+1}^{n} p^i(t)\left[C^i(t)-Q^i(t)\right]\equiv 0$$

Consistent production and consumption in period t should allow the realization of planned asset purchases in period $t+1$, $D^j(t,t+1,t+1)$, at the asset prices expected to prevail in $t+1$. Note that this is not a constraint on current market excess demands. An interpretation of Kuska's error in terms of the beginning-of-period specification is that he replaces the psychological budget constraint by the invalid market budget constraint:

$$\sum_{j=1}^{m} p^j(t)\left[D^i(t,t,t)-S^i(t)\right]+\sum_{i=m+1}^{n} p^i(t)\left[C^i(t)-Q^i(t)\right]\equiv 0$$

[6]Neo-Keynesian models with real capital include a flow equilibrium specification for investment rather than a capital stock equilibrium condition. Turnovsky (1977) justifies this approach by introducing adjustment costs.

[7]Consistency requires that

$$\sum_{j=1}^{m} p^j(t)\left[D_2^j(t,t,t)+D_3^j(t,t,t)\right]=\sum_{i=1}^{n}\left[q^i(t)-c^i(t)\right]p^i(t)$$

The only three consistent sets of market equilibrium conditions and budget or balance sheet constraints are (1) and (2) in the discrete-time end-of-period model, (3), (4), and (5), in the discrete-time beginning-of-period model, and (6), (7), and (8) in the continuous-time version of either model. Kuska's equations (21) and (22) do not correspond to any of these consistent configurations. His Propositions 2 and 4 are consequently invalid. The next section illustrates the compatability of balance of payments disequilibrium with asset market equilibrium in a discrete-time end-of-period model.[8]

II. The Two-Economy *IS-LM* Model: Discrete-Time End-of-Period Specification

Consider two countries each of which produces a distinct output in perfectly elastic supply at a price fixed in terms of domestic currency. The two countries trade their outputs. As we consider only a fixed exchange rate regime, relative price changes and changes in the general price level are ignored.[9] The governments of both countries issue two forms of debt, money and bonds. Money bears no interest. M_t and M_t^* are the amounts of money issued at the beginning of period t by home and foreign governments, respectively. Each country's bond is a perpetuity paying one unit of currency in each period. Let A_t and A_t^* denote the number of domestic and foreign bonds respectively outstanding at the beginning of period t. The values of the stocks of bonds outstanding at the beginning of period t are thus A_t/r_t and A_t^*/r_t^*, respectively, while the values of net new bond issues during the period are $(A_{t+1}-A_t)/r_t$ and $(A_{t+1}^*-A_t^*)/r_t^*$, respectively. Interest payments on the outstanding debt during period t are given by A_t and A_t^*, respectively. For simplicity we ignore physical capital as an asset and investment as a flow demand for output.

First we state the budget constraints for the public (consolidated treasury and central bank) and private (consolidated corporate and household) sectors from which we derive the balance of payments or external sector accounts. We then impose market equilibrium conditions and behavioral relationships. Kuska's equations (9) through (20) constitute a special case of this model. We generalize it by including nonhuman wealth as an argument in money and consumption-demand functions, thus overcoming the problem raised by Kuska's valid Proposition 1. The model has the property that simultaneous money-market equilibrium and balance of payments disequilibrium are compatible, contrary to Kuska's Propositions 2 and 4. In addition, in the case of zero capital mobility, one asset-market equilibrium condition is redundant *in each country*, in contradiction with Kuska's Proposition 3.

A. *Sectoral Budget Constraints*

1. *The Public Sector*

Home government liabilities outstanding at the beginning of period t consist of bonds held by the domestic private sector A_t^d, and the foreign private sector A_t^f, plus money held by the domestic private sector in amount M_t^d, and the foreign government in amount M_t^f. The corresponding magnitudes for the foreign government are A_t^{*f}, A_t^{*d}, M_t^{*f}, and M_t^{*d}. In each case magnitudes are measured in terms of local currency. Government assets consist of reserves in the form of foreign money, held in amount $e_t M_t^{*d}$ by the home country government and $(1/e_t)M_t^f$ by the foreign government. Here e denotes the spot price of foreign currency in terms of domestic currency. The Appendix summarizes our variable definitions for this model. The budget constraint for the home-country

in the continuous-time version of the end-of-period model and that

$$\sum_{j=1}^{m} p^j(t)\left[D_3^j(t,t,t)\right]=\sum_{i=1}^{n} p^i(t)\left[q^i(t)-c^i(t)\right]$$

in the continuous-time version of the beginning-of-period model. (We assume $\hat{p}^i(t,t)=p^i(t)$). The D_k^j denotes the partial derivative of the demand for asset j with respect to the time at which demand is expressed in the market ($k=2$) and with respect to the time of delivery ($k=3$).

[8]The continuous time case is not considered in detail. For a complete treatment, see our earlier paper.

[9]Buiter (1978) considers the consequences of allowing import prices and exchange rate changes to affect the overall price level and thus the real value of assets denominated in domestic currency in a Keynesian open-economy model.

government is given by:[10]

$$(9)\quad G_t+A_t^d+A_t^f-T_t\equiv\frac{1}{r_t}\Delta A_t^d+\frac{1}{r_t}\Delta A_t^f+\Delta M_t^d+\Delta M_t^f-e_t\Delta M_t^{*d}$$

Here Δ denotes the forward difference operator; $\Delta Z_t=Z_{t+1}-Z_t$. We assume that government spending and financing plans are always fulfilled so that (9) holds both *ex ante* and *ex post*. We assume, for simplicity, that the government does not buy foreign goods. Similarly, in the foreign country,[11]

$$(10)\quad G_t^*+A_t^{*d}+A_t^{*f}-T_t^*\equiv\frac{1}{r_t^*}\Delta A_t^{*d}+\frac{1}{r_t^*}\Delta A_t^{*f}+\Delta M_t^{*}d+\Delta M_t^{*f}-\frac{1}{e_t}\Delta M_t^f$$

The government must finance its current account deficit, public consumption plus debt service less tax revenue, by increasing its liabilities or spending its reserves. The official settlements surplus of the home country (the deficit of the foreign country) is $e_t\Delta M_t^{*d}-\Delta M_t^f$, measured in terms of the home currency.

2. *The Private Sector*

The private sector in the home country holds as assets only domestic money and foreign and domestic bonds. In period t, $Y_t+A_t^d+e_tA_t^{*d}-T_t$ is earned after taxes, where Y_t denotes total income. Home-country *ex ante* private absorption in period t consists of C_t^h of domestic output and $e_tC_t^{*d}$ of foreign output.

If we denote home-country end-of-period demand for domestic bonds as $H_{t,t+1}$, home-country demand for foreign bonds as $J_{t,t+1}$[12] and home-country demand for money as $L_{t,t+1}$, the *ex ante* private sector budget constraint is

$$(11)\quad Y_t-T_t+A_t^d+e_tA_t^{*d}-C_t^d-e_tC_t^{*d}\equiv H_{t,t+1}-\frac{1}{r_t}A_t^d+J_{t,t+1}-\frac{e_t}{r_t^*}A_t^{*d}+L_{t,t+1}-M_t^d$$

Assuming consumption plans are realized, which will be the case if commodity markets clear, the *ex post* budget constraint is[13]

$$(12)\quad Y_t-T_t+A_t^d+e_tA_t^{*d}-C_t^d-e_tC_t^{*d}\equiv\frac{1}{r_t}\Delta A_t^d+\frac{e_t}{r_t^*}\Delta A_t^{*d}+\Delta M_t^d$$

The corresponding *ex ante* (13) and *ex post* (14) budget constraints for the private sector of the foreign country are

$$(13)\quad Y_t^*-T_t^*+A_t^{*f}+\frac{1}{e_t}A_t^f-C_t^{*f}-\frac{1}{e_t}C_t^f\equiv H_{t,t+1}^*-\frac{1}{e_tr_t}A_t^f+J_{t,t+1}^*-\frac{1}{r_t^*}A_t^{*f}+L_{t,t+1}^*-M_t^{*f}$$

$$(14)\quad Y_t^*-T_t^*+A_t^{*f}+\frac{1}{e_t}A_t^f-C_t^{*f}-\frac{1}{e_t}C_t^f\equiv\frac{1}{r_t^*}\Delta A_t^{*f}+\frac{1}{e_tr_t}\Delta A_t^f+\Delta M_t^{*f}$$

[10]We note that Kuska misstates the government budget constraint in his equations (31) and (32). The *stock* demand for bonds is equated to the *increment* in the money supply. This error is carried over into the subsequent equations (33) and (34).

[11]In continuous time the *ex post* public sector budget constraint is

$$g+A^d+A^f-\tau\equiv\frac{1}{r}(\dot{A}^d+\dot{A}^f)+\dot{M}^d+\dot{M}^f-e\dot{M}^{*d}$$

where lowercase letters denote instantaneous flows and τ instantaneous tax receipts.

[12]Asset demands are *real* demands. Thus L, H, and J are demands for certain amounts of purchasing power in terms of the domestic price level while L^*, H^*, and J^* are demands for certain amounts of purchasing power in terms of the foreign price level.

[13]In continuous time the *ex post* private sector budget constraint is

$$c^d+ec^{*d}+\frac{1}{r}\dot{A}^d+\frac{e}{r^*}\dot{A}^{*d}+\dot{M}^d\equiv y-\tau+A^d+eA^{*d}$$

. *The Balance of Payments*

Adding the public (9) and private *ex post* 12) budget constraints of the home country 'ields

$$15)\quad \left[G_t+C_t^d+e_tC_t^{*d}+A_t^f-e_tA_t^{*d}-Y_t\right] + \left[\frac{e_t}{r_t^*}\Delta A_t^{*d}-\frac{1}{r_t}\Delta A_t^f\right] + \left[e_t\Delta M_t^{*d}-\Delta M_t^f\right]\equiv 0$$

The term in the first square brackets of (15), which we denote $-B_T$, corresponds to the current account deficit of the home country. The second term, denoted $-F$, is the capital account deficit or net outflow of funds. Finally, the third term, B, denotes the official settlements balance.[14] Thus $-B_T-F+B\equiv 0$. Similarly, for the foreign country

$$(16)\quad \left[G_t^*+C_t^{*f}+\frac{1}{e_t}C_t^f+A_t^{*d}-\frac{1}{e_t}A_t^f-Y_t^*\right] + \left[\frac{1}{e_tr_t}\Delta A_t^f-\frac{1}{r_t^*}\Delta A_t^{*d}\right]+\left[\frac{1}{e_t}\Delta M_t^f-\Delta M_t^{*d}\right] \equiv -B_T^*-F^*+B^*\equiv 0$$

Since $B=-eB^*$ and $F=-eF^*$, we have $B_T=-eB_T^*$. The *ex ante* balance of payments constraints can be found for the home country by adding (9) and (11), and for the foreign country by adding (10) and (13).

B. *Market Equilibrium*

In the most general version of the model, there are six goods, money, bonds, and output, each of which may originate from the home or foreign country. We now show that asset-market equilibrium is consistent with nonzero values of the current account and/or the official settlements balance.

The six market clearing conditions are[15, 16]

$$(17)\qquad L_{t,t+1}=M_t^d+\Delta M_t^d$$

$$(18)\qquad L_{t,t+1}^*=M_t^{*f}+\Delta M_t^{*f}$$

$$(19)\quad H_{t,t+1}+e_tH_{t,t+1}^* =(1/r_t)\left[A_t^d+\Delta A_t^d+A_t^f+\Delta A_t^f\right]$$

$$(20)\quad J_{t,t+1}^*+(1/e_t)J_{t,t+1} =(1/r_t^*)\left[A_t^{*f}+\Delta A_t^{*f}+A_t^{*d}+\Delta A_t^{*d}\right]$$

$$(21)\qquad G_t+C_t^d+C_t^f=Y_t$$

$$(22)\qquad G_t^*+C_t^{*d}+C_t^{*f}=Y_t^*$$

1. *Kuska's Proposition* 3

In general, only one equilibrium condition can be suppressed. Substitute the money and output market equilibrium conditions, (17) and (21), and the government budget con-

[14]In continuous time the current, capital, and official settlements balances for the home country are

$$b_T\equiv y+eA^{*d}-A^f-g-c^d-ec^{*d};$$

$$f\equiv\frac{1}{r}\dot{A}^f-\frac{e}{r^*}\dot{A}^{*d};\ b\equiv e\dot{M}^{*d}-\dot{M}^f$$

Note that $b_T+f-b\equiv 0$.

[15]We can rephrase (21) and (22) as *IS* equilibrium conditions. Adding and subtracting $(e_tC_t^{*d}+A_t^f-e_tA_t^{*d})$ from (21) we obtain

$$G_t+\left(C_t^d+e_tC_t^{*d}\right)+A_t^f-e_tA_t^{*d}+\left(C_t^f-e_tC_t^{*d}\right) =Y+A_t^f-e_tA_t^{*d}$$

Let $C_t=C_t^d+e_tC_t^{*d}$ be total home-country consumption, $X_t=C_t^f+e_tA_t^{*d}$ be home-country exports, including services, and $Z_t=e_tC_t^{*d}+A_t^f$ be home-country imports, including services. Thus (21) is equivalent to $G_t+C_t+X_t-Z_t=Y_t+e_tA_t^{*d}-A^f$. A similar derivation, from (22), obtains for the foreign country.

[16]In continuous time, the six market equilibrium conditions are

$$L=M^d;\ L^*=M^{*f};\ H+eH^*=\frac{1}{r}(A^d+A^f);$$

$$J^*+\frac{1}{e}J=\frac{1}{r^*}(A^{*f}+A^{*d});$$

$$g+c^d+c^f=y;\ g^*+c^{*f}+c^{*d}=y^*$$

straint (9) into the household budget constraint (12) and use the fact that when commodity markets clear, the *ex post* balance of payments identity can be written as

$$C_t^f - e_t C_t^{*d} + e_t A_t^{*d} + \frac{1}{r_t}\Delta A_t^f$$

$$- \frac{e}{r^*}\Delta A_t^{*d} + \Delta M_t^f - e\Delta M_t^{*d} \equiv 0.$$

This yields[17]

$$(23) \qquad \left(H_{t,t+1} - \frac{1}{r_t}\left(A_t^d + \Delta A_t^d\right)\right)$$

$$+ \left(J_{t,t+1} - \frac{e_t}{r_t^*}\left(A_t^{*d} + \Delta A_t^{*d}\right)\right) = 0$$

In the same way we find for the foreign country:

$$(24) \qquad \left(H_{t,t+1}^* - \frac{1}{e_t r_t}\left(A_t^f + \Delta A_t^f\right)\right)$$

$$+ \left(J_{t,t+1}^* - \frac{1}{r_t^*}\left(A_t^{*f} + \Delta A_t^{*f}\right)\right) = 0$$

Commodity and money markets are in equilibrium, but an excess demand may exist for one type of bond with an offsetting excess supply for the other. Adding together (23) and e_t times (24) yields the sum of (19) and e_t times (20). If money markets and output markets clear and (19) holds, then so does (20). *One* market, in general, may be suppressed. If Kuska's Proposition 3 had been directed at models in which bonds are traded internationally, it would have been correct. When bonds are *not* traded, however, which is the case Kuska considers, the second term in (23) and the first term in (24) become zero. These equations reduce to the equilibrium conditions in the bond markets, equations (19) and (20). When bonds are not traded, then, bond-market equilibrium *in each country* is implied by money-marke equilibrium *in that country* and equilibriun in the two commodity markets. Both (19 and (20) must be suppressed, contrary tc Kuska's Proposition 3.[18]

2. *Kuska's Propositions* 2 *and* 4

Equilibrium conditions (17), (18), (19), and (20) equate end-of-period asset demands tc end-of-period supplies. Beginning-of-period supplies, inherited from the previous period, are exogenous while current period flows are endogenous or policy determined. Substituting (17) through (22) into the balance of payments conditions (15) and (16) reveals that asset-market equilibrium does not imply either that $B_T = 0$ or $B = 0$. We show this explicitly in Section *D* below.

C. *Asset Demand Functions and Kuska's Proposition* 1

We complete our specification of an *IS-LM* Keynesian model by introducing asset and commodity demand functions. The resulting two-country model corresponds in essential respects to Kuska's equations (9)–(20). One modification, however, meets the criticism of the treatment of wealth or asset stocks in asset demand functions raised in Kuska's Proposition 1.

Brainard and Tobin have provided ample examples of the often bizarre implications for the suppressed excess demand function implied by the specification of nonsuppressed equations and Walras' Law. An appropriate response to this criticism is to include nonhuman wealth as an argument in private sector demand functions. We define home-country and foreign-country private wealth, respectively, as W_t and W_t^* where[19]

$$(25) \qquad W_t \equiv M_t^d + \frac{1}{r_t}A_t^d + \frac{e_t}{r_t^*}A_t^{*d}$$

$$(26) \qquad W_t^* \equiv M_t^{*f} + \frac{1}{r_t^*}A_t^{*f} + \frac{1}{r_t e_t}A_t^f$$

[17]In continuous time the *ex ante* private sector balance sheet constraints for the two countries are

$$L + H + J \equiv M^d + \frac{1}{r}A^d + \frac{e}{r^*}A^{*d};$$

$$L^* + H^* + J^* \equiv M^{*f} + \frac{1}{r^*}A^{*f} + \frac{1}{er}A^f$$

[18]The assignment of the bond-market equilibrium conditions as the residual ones is arbitrary. We follow the approach adopted by Kuska.

[19]The issue as to whether or not domestically held government bonds constitute net wealth need not detain us here.

We also define home-country and foreign disposable income, $\tilde{Y}_t$ and $\tilde{Y}_t^*$, as

$$(27)\qquad \tilde{Y}_t \equiv Y_t + A_t^d + e_t A_t^{*d} - T_t$$

$$(28)\qquad \tilde{Y}_t^* \equiv Y_t^* + A_t^{*f} + \frac{1}{e_t} A_t^f - T_t^*$$

We specify end-of-period asset demands and consumption demands as follows:

$$(29)\qquad L_{t,t+1} = L(r_t, r_t^*, \tilde{Y}_t, W_t);$$

$$L_r \leqslant 0,\quad L_{r^*} \leqslant 0,\quad L_{\tilde{Y}} \geqslant 0,\quad 1 \geqslant L_W \geqslant 0$$

$$(30)\qquad H_{t,t+1} = H(r_t, r_t^*, \tilde{Y}_t, W_t);$$

$$H_r \geqslant 0,\quad H_{r^*} \leqslant 0,\quad 1 \geqslant H_W \geqslant 0$$

$$(31)\qquad C_t^d = C^d(r_t, r_t^*, e_t, \tilde{Y}_t, W_t);$$

$$C_r^d \leqslant 0,\quad C_{r^*}^d \leqslant 0,\quad C_e^d \geqslant 0$$

$$0 \leqslant C_{\tilde{Y}}^d \leqslant 1,\quad C_W^d \geqslant 0$$

$$(32)\qquad C_t^{*d} = C^{*d}(r_t, r_t^*, e_t, \tilde{Y}_t, W_t);$$

$$C_r^{*d} \leqslant 0,\quad C_{r^*}^{*d} \leqslant 0;\quad \frac{\partial}{\partial e}(eC^{*d}) \leqslant 0$$

$$0 \leqslant C_{\tilde{Y}}^{*d} \leqslant 1,\quad C_W^{*d} \geqslant 0$$

$$(33)\qquad L_{t,t+1}^* = L^*(r_t, r_t^*, \tilde{Y}_t^*, W_t^*),$$

$$L_r^* \leqslant 0,\quad L_{r^*}^* \leqslant 0,\quad L_{\tilde{Y}}^* \geqslant 0,\quad 1 \geqslant L_{W^*}^* \geqslant 0$$

$$(34)\qquad H_{t,t+1}^* = H^*(r_t, r_t^*, \tilde{Y}_t^*, W_t^*),$$

$$H_r^* \geqslant 0,\quad H_{r^*}^* \leqslant 0,\quad 1 \geqslant H_{W^*}^* \geqslant 0$$

$$(35)\qquad C^{*f} = C^{*f}(r_t, r_t^*, e_t, \tilde{Y}_t^*, W_t^*),$$

$$C_r^{*d} \leqslant 0,\quad C_{r^*}^{*d} \leqslant 0,\quad C_e^{*d} \leqslant 0$$

$$0 \leqslant C_{\tilde{Y}^*}^{*d} \leqslant 1,\quad C_{W^*}^{*d} \geqslant 0$$

$$(36)\qquad C_t^f = C^f(r_t, r_t^*, e_t, \tilde{Y}_t^*, W_t^*),$$

$$C_r^f \leqslant 0;\quad C_{r^*}^f \leqslant 0;\quad \frac{\partial}{\partial e}\left(\frac{1}{e} C^f\right) \geqslant 0$$

$$0 \leqslant C_{\tilde{Y}^*}^f \leqslant 1,\quad C_{W^*}^f \geqslant 0$$

From the private sector budget constraints

$$(37)\qquad L_{t,t+1} + H_{t,t+1} + J_{t,t+1} + C_t^d + e_t C_t^{*d} \equiv W_t + \tilde{Y}_t$$

$$(38)\qquad L_{t,t+1}^* + H_{t,t+1}^* + J_{t,t+1}^* + C_t^{*f} + \frac{1}{e_t} C_t^f \equiv W_t^* + \tilde{Y}_t^*$$

equations (29) through (32) and (33) through (36) define demand for bond functions[20]

$$(39)\qquad J(r_t, r_t^*, Y_t^d, W_t);$$

$$J_r \leqslant 0,\ J_{r^*} \geqslant 0;\ J_W \geqslant 0$$

$$(40)\qquad J^*(r_t, r_t^*, Y_t^{*d}, W_t^*);$$

$$J_r^* \leqslant 0,\ J_{r^*}^* \geqslant 0,\ J_{W^*}^* \geqslant 0$$

These demand functions have the properties that: 1) assets are gross substitutes; 2) the demand for all assets and consumption increase in wealth; 3) the demand for money and consumption increase in income; and 4) an increase in the exchange rate shifts consumption away from imports toward domestic output. Since W_t appears as an argument in all domestic demand functions, it is no longer true that "... *any* exogenous increase in the quantity of bonds will be willingly held..." (Kuska, p. 660). An exogenous increase in bond supply, raising wealth, will affect demands for all other assets and commodities. After substituting the demand functions (29)–(36) into the six equilibrium conditions (17) through (22) and using Walras' Law to omit one market-clearing condition, we have a system of five independent equations. The endogenous variables are r_t, r_t^*, Y_t, Y_t^*, and either ΔM_t^d or ΔM_t^{*f}. As long as bonds are traded internationally, one government cannot control its money supply even in the short run, regardless of the degree of substitutability between foreign

[20]The restrictions we impose on the signs of the partial derivatives of J and J^* are not the only possible ones. They are consistent with the restrictions imposed in (29)–(36) and the budget constraints.

and domestic bonds.[21] If, however, bonds are *not* traded at all, only four of (29) through (36) are independent and both ΔM_t and ΔM_t^* can be controlled by the policy authorities; subject to their budget constraints, both governments can choose their money stocks independently.

D. *A Model Without Capital Mobility*

Kuska's equations (9)–(20) assume no international trade occurs in bonds. Since this assumption simplifies the analysis and permits us to illustrate the compatibility of asset-market equilibrium with a nonzero balance of payments in a particularly simple way, we also adopt it here. To incorporate this assumption set $J_{t,t+1} \equiv H^*_{t,t+1} \equiv A_t^{*d} \equiv A_t^f \equiv \Delta A_t^f \equiv \Delta A_t^{*d} \equiv 0$. Foreign interest rates no longer appear as arguments in domestic behavioral relationships, and vice versa. For simplicity we set

$$T_t = A_t^d \tag{41}$$

$$T_t^* = A_t^{*f} \tag{42}$$

so that $\tilde{Y}_t = Y_t$ and $\tilde{Y}_t^* = Y_t^*$. Kuska also sets $G_t = G_t^* = 0$. We will not yet incorporate this assumption.

As a result of these assumptions, then, we have four *independent* market equilibrium conditions.

$$L(r_t, Y_t, W_t) = M_t^d + \Delta M_t^d \tag{43}$$

$$L^*(r_t^*, Y_t^*, W_t^*) = M_t^{*f} + \Delta M_t^{*f} \tag{44}$$

$$G_t + C^d(r_t, e_t, Y_t, W_t) + C^f(r_t^*, e_t, Y_t^*, W_t^*) = Y_t \tag{45}$$

$$G_t^* + C^{*f}(r_t^*, e_t, Y_t^*, W_t^*) + C^{*d}(r_t, e_t, Y_t, W_t) = Y_t^* \tag{46}$$

[21] If we generalize this to n countries, $n-1$ countries are unable to control their domestic money supplies. Note also that the asset-market equilibrium conditions are only completely specified when we know the financing policies of the government whose money supply is not endogenously determined. If this is the home country, we need to know $(1/r)(\Delta A^d + \Delta A^f)$ and $(1/r)\Delta M^d$ (assuming G and T to be given).

The public and private sector budget constraints are[22]

$$G_t \equiv \frac{1}{r_t}\Delta A_t^d + \Delta M_t^d + \Delta M_t^f - e_t \Delta M_t^{*d} \tag{47}$$

$$G_t^* \equiv \frac{1}{r_t^*}\Delta A_t^{*f} + \Delta M_t^{*f} + \Delta M_t^{*d} - (1/e_t)\Delta M_t^f \tag{48}$$

$$C_t^d + e_t C_t^{*d} + \frac{1}{r_t}\Delta A_t^d + \Delta M_t^d \equiv Y_t \tag{49}$$

$$C_t^{*f} + \frac{1}{e_t} C_t^f + \frac{1}{r_t^*}\Delta A_t^{*f} + \Delta M_t^{*f} \equiv Y_t^* \tag{50}$$

The private wealth definitions are

$$W_t \equiv M_t^d + \frac{1}{r_t} A_t^d \tag{51}$$

$$W_t^* \equiv M_t^{*f} + \frac{1}{r_t^*} A_t^{*f} \tag{52}$$

Note that the private sector budget constraints (49) and (50) are implied by equations (43)–(48).

After substituting for W_t and W_t^*, equations (43) through (46) determine equilibrium values of r_t, r_t^*, Y_t and Y_t^*. Alternatively, if the government in the home country pegs r_t, ΔM_t is endogenous and r_t exogenous. Similarly, if the foreign government pegs r_t^*, ΔM_t^* is endogenous.

1. *Kuska's Propositions* 2 *and* 4 *Again*

The balance of payments B, which is now equivalent to the current account balance B_T, is from (16)

$$B_T = B = Y_t - G_t - C_t^d - e_t C_t^{*d} \tag{53}$$

[22] The asset-market equilibrium conditions (43) and (44) are only fully and completely specified when the public sectors have decided upon their mixes of domestic borrowing and domestic credit creation: $(1/r)\Delta A^d$ and ΔM^d for the home country government sector, $(1/r)^*\Delta A^{*f}$ and ΔM^{*f} for the foreign country government sector.

Substituting (21) into (53) gives

$$B_T = B = C_t^f - e_t C_t^{*d} \tag{54}$$

while (16) implies[23]

$$B_T = B = e_t \Delta M_t^{*d} - \Delta M_t^f \tag{55}$$

The first expression corresponds to the "absorption approach" view of the balance of payments, the second to the "elasticities approach" and the third to the "monetary approach." The three are of course equivalent, as implied by the sectoral budget constraints. Using the monetary approach equation, expression (55), the home-country government budget constraint, (47), implies that[24]

$$B \equiv \frac{1}{r_t} \Delta A_t^d + \Delta M_t^d - G_t \tag{56}$$

which, if asset markets are in end-of-period equilibrium, becomes

$$B = \left(H_{t,t+1} - \frac{1}{r_t} A_t^d \right) + \left(L_{t,t+1} - M_t^d \right) - G_t \tag{57}$$

Asset-market equilibrium does not imply that $B=0$. It simply implies that the sum of the planned and actual changes in the money stock and bond stock equal the sum of the balance of payments surplus and government deficit. If $G_t = 0$ as Kuska implicitly assumes, then the govenment can fully sterilize the deficit by setting $\Delta A_t^d / r_t = B$, while zero sterilization implies $\Delta A_t^d / r_t = 0$. In the first case not only is the beginning-of-period money stock exogenous, but so is the end-of-period stock. A deficit country can, of course, continue to sterilize only so long as $A_t^d > 0$ or until it either runs out of international reserves or finds the surplus country unwilling to accumulate its currency in the form of reserves. Even if a sterilization policy is pursued, so that the money supply remains constant, an imbalance of payments implies that the private sector in the deficit country is losing assets, thus lowering its wealth and therefore its demand for imports. Similarly the surplus country is gaining assets, increasing its demand for imports. Nevertheless, end-of-period asset-market equilibrium is maintained each period. If the model is stable the transfer of wealth will cause the two countries eventually to attain balance of payments equilibrium. This will be a *stationary equilibrium* in which asset supplies are constant.

Kuska's error is apparent in our equation (56). His equations (21) and (22) erroneously define asset-market equilibrium as the equality of beginning-of-period supplies and end-of-period demands. When these are equal, B is indeed constrained at 0 (as long as the government balances its budget). The requirement that all stocks remain constant does indeed imply that $B=0$. This is a property of long-run stationary equilibrium and not of end-of-period asset-market equilibrium.

III. Conclusion

Standard textbook treatments of Keynesian balance of payments theory (see, for example, David J. Ott, Attiat F. Ott and Jang H. Yoo, and Branson, 1979) are nested within the general framework presented in Section II. We have shown elsewhere (1979) that the model developed in Section II can be described in terms of the "*IS-LM-BP*" analysis used, for instance, by Branson (1979, ch. 15). While balance of payments theorists should always pay careful attention to balance sheet constraints, budget constraints and Walras' Law, the literature which Kuska attacks is free of conceptual error on these grounds.

APPENDIX

G domestic government spending on domestic output; $G = g\Delta t$

T domestic taxes net of transfers [excluding interest on public debt]; $T = \tau \Delta t$

G^* foreign government spending on foreign output; $G^* = g^* \Delta t$

[23] In continuous time, the trade balance which in this case equals the overall balance of payments is given by $b_T \equiv b \equiv y + eA^{*d} - A^f - g - c^d - ec^{*d} = c^f - ec^{*d} + eA^{*d} - A^f = e\dot{M}^{*d} - \dot{M}^f$.

[24] In continuous time this becomes $b \equiv (1/r)\dot{A}^d + \dot{M}^d - g$.

T^* foreign taxes net of transfers [excluding interest on public debt]; $T^*=\tau^*\Delta t$
C^d Domestic consumption demand for domestic output; $C^d=c^d\Delta t$
C^{*d} domestic consumption demand for foreign output; $C^{*d}=c^{*d}\Delta t$
C^f foreign consumption demand for domestic output; $C^f=c^f\Delta t$
C^{*f} foreign consumption demand for foreign output; $C^{*f}=c^{*f}\Delta t$
L private domestic demand for domestic money
L^* private foreign demand for foreign money
H private domestic demand for domestic government bonds
H^* private foreign demand for domestic government bonds
J private domestic demand for foreign government bonds
J^* private foreign demand for foreign government bonds
Y domestic output; $Y=y\Delta t$
Y^* foreign output; $Y=y^*\Delta t$
$\tilde{Y}$ domestic personal disposable income; $\tilde{Y}=\tilde{y}\Delta t$
$\tilde{Y}^*$ foreign personal disposable income; $\tilde{Y}^*=\tilde{y}^*\Delta t$
B_T domestic current account surplus; $B_T=b_T\Delta t$
F domestic private capital account surplus; $F=f\Delta t$
B domestic official settlements account surplus; $B=b\Delta t$
B_T^* foreign current account surplus; $B_T^*=b_T^*\Delta t$
F^* foreign capital account surplus; $F^*=f^*\Delta t$
B^* foreign official settlements account surplus; $B^*=b^*\Delta t$
W private domestic nonhuman wealth
W^* private foreign nonhuman wealth
A^d domestic private holdings of domestic government debt
A^f foreign private holdings of domestic government debt
M^d domestic private holdings of domestic money
M^f foreign official holdings of domestic money
A^{*f} foreign private holdings of foreign government debt
A^{*d} domestic private holdings of foreign government debt
M^{*f} foreign private holdings of foreign money
M^{*d} domestic official holdings of foreign money
r domestic interest rate
r^* foreign interest rate
e foreign exchange rate [spot]
Δ forward difference operator
$\dot{x}$ $\equiv dx/dt$

Time subscripts of stocks refer to the beginning of the period.

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The Output Distribution Frontier: Comment

By DONALD KEENAN AND PAUL H. RUBIN*

In a recent paper in this *Review*, William Baumol and Dietrich Fischer (hereafter B-F) argue that it is impossible to achieve income equality via taxes and transfers without resulting in zero output, whereas it is quite possible to attain equality by means of discriminatory wage policy. A first reading of the paper gives the impression that wage policy can achieve what tax policy cannot, which is at odds with the obvious proposition that the effects of discriminatory wages can always be accomplished by the appropriate selection of taxes and transfers. The difficulty is seen to lie not in the nature of the two kinds of policies, but in their asymmetric treatment by B-F. That is, their tax schedule is to be uniformly applied to all persons by income, without prior consideration of characteristics of individuals, whereas the wage policy is chosen with knowledge of the individual characteristics of workers and allows for their discriminatory treatment. It is clear that if these latter possibilities had been permitted of tax policies, they too could have achieved income equality at positive output.

To the extent that the information requirements of discriminatory policy seem excessive, one can conclude that income equality is unobtainable in practice under both tax and wage policies. This is further supported by the realization that, with a longer run perspective, discriminatory wages introduce incentive problems in the acquisition of human capital. In addition we shall see that the B-F paper contains certain logical errors which vitiate or at least modify several of their statements.

I. Tax Policy

The basic argument of B-F regarding tax policy is contained in three propositions:

PROPOSITION 1: *If different individuals have different budget curves between income and retained input (after transfers and taxes) or if they share a negative slope over any interval, then there exist utility functions for which the final distribution of income will be unequal.* [p. 515]

PROPOSITION 2: *In an economy with a large number of persons, if individuals are not sated in incomes or retained input, and if zero input supplies yield zero output, then any system of progressive taxes and transfers that guarantees equality of incomes must yield zero output in the economy.* [p. 516]

PROPOSITION 3: *If only progressive taxes and transfers are used to redistribute incomes and the feasible region in y_i space is bounded and the derivatives of its boundary are continuous, and if the normal variations property holds, then a feasible region that contains any positive solution $y_1^* > 0$, $y_2^* > 0$ for any pair of individuals, 1, 2 must have a frontier that contains some positively sloping segment.* [p. 517]

The feasible set is composed of those income pairs y_1^* and y_2^* of the two individuals that are chosen for some tax-transfer scheme. The normal variations property requires that individual's preferences be dissimilar.

In Propositions 1 and 2 the simple argument is made that knowing nothing of individuals' characteristics, one can be sure to attain income equality only by having everyone's income be zero. In the subsequent discussion they make much use of the output distribution frontier. While its origin is never explicitly identified, consideration makes clear that it must have been obtained by applying various tax-transfer schedules to two persons with fixed characteristics; that is, characteristics of individuals are held fixed while tax schemes are allowed to vary. Again, while it is not explicitly stated, for certain of

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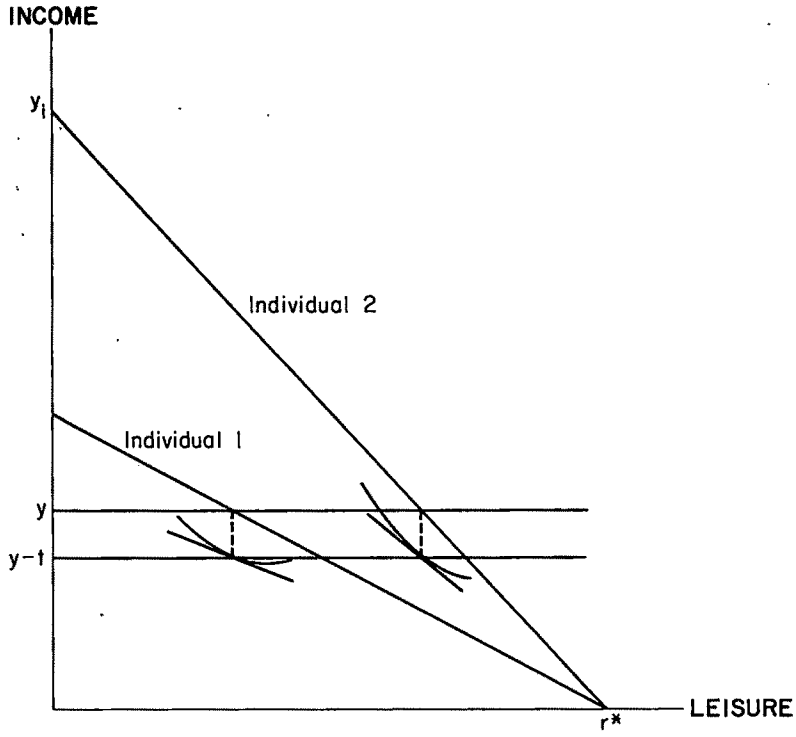

FIGURE 1. r^* = TIME ENDOWMENT; y_i = INCOME OF iTH PERSON; t = TAX; w_i = WAGE RATE OF THE iTH PERSON; v_i = LEISURE OF iTH PERSON; AND WHERE $y_i = w_i r^* - w_i v_i$.

their claims to make sense, B-F must be requiring that taxes and transfers are applied uniformly, depending only on a person's income level. In employing their output frontier, B-F make much use of Proposition 2, but in all cases such arguments are unjustified. The basic fallacy in their argument is that just because income equality can be achieved only by zero output whenever individual characteristics are allowed to be arbitrary does not imply that given two persons with definite characteristics, no uniform tax-transfer scheme can equalize their incomes. That is, in proving Proposition 2 characteristics of individuals are allowed to vary while tax-transfer schemes are held fixed, but in deriving the output distribution frontier, characteristics are held fixed and tax schemes are allowed to vary; these procedures are not equivalent. It certainly does not follow from Proposition 2 that the normal variation property requires that income equality can be achieved for two such persons only at zero output.

One can easily produce examples obeying the normal property where some uniform tax transfer scheme equalizes income at positive output. In Figure 1 we indicate how an example equalizing incomes can be constructed. The diagram superimposes the labor-leisure tradeoffs of two persons with different wages and for the chosen income level y assigns a tax t. If the preferences of persons 1 and 2 are chosen such that $(MRS_1/w_1)(y-t, v_1) = (MRS_2/w_2)(y-t, v_2)$ a local requirement, then interpreting this common value as $(1-t')$ with $t'(y)$ being the marginal tax rate, one can easily extend the tax schedule and individual preferences so that y is the optimal choice of each person (see Figure 1 or B-F for notation). What is more, by using the perturbation arguments of transversality theory, one can show that all nearby individual characteristics also per-

mit income equality, so that the measure of such cases is positive and they cannot be considered insignificant. What is interesting is that, while this is true of two or three persons, it fails for four or more persons (see the Appendix) so that the large number assumption introduced by B-F in Proposition 2 serves a purpose beyond the removal of those indirect effects of tax transfer schemes mentioned in their footnote 3.

As it stands, Proposition 3 is false since $y_1 = y_2 = 0$ need not be on the frontier. The corollary following ("*Using only progressive income taxes and transfers to redistribute incomes, the efficient set in y_1, y_2 space must be discontinuous*," p. 517) makes no sense at all since $y_1 = y_2 = 0$ is not an efficient point in any case, the whole argument of Proposition 3 being based on the premise that there exists a $y_1^* > 0$, $y_2^* > 0$ dominating the origin. Not only is the discussion following the corollary false for more than three persons as we have already noted, but the interpretation presented seems misleading. Whatever the number of individuals, it is certainly true that some tax-transfer scheme of a discriminatory nature can obtain identical incomes at positive output. (Here, as B-F do other than in footnote 3, we ignore the problem of financing the tax-transfer scheme). The difficulty is that one has simply asked too much of a tax scheme in requiring that it should both equalize incomes and treat everyone equally by income.

II. Wage Policy

It is a main point of our discussion that the alternative wage discrimination income equalization scheme is misleading to the extent that, while the letter of the B-F article may not claim it, one is left with the strong impression that wage policies succeed where tax schemes fail. Surely numerous statements made throughout the B-F article suggest this. However, it should now be clear that the major source of difference in the two types of policies presented is that the tax scheme is arbitrarily required to be uniformly applied and is chosen without consideration of individuals' characteristics, whereas the wage scheme, equally arbitrarily, permits both individuals' characteristics to be considered a priori and persons to be treated in a discriminatory manner. It is hardly surprising, then, that the latter scheme succeeds where the former fails. Certainly the reader would have been better served if the comparison had been made between a tax scheme with and without these informational complexities so that the real source of difference would be revealed.

While the wage discrimination scheme might hold some promise in the short run, it is not difficult to convince oneself that it presents serious incentive difficulties in the long run.[1] Baumol and Fischer argue that "If doctors and ditch diggers are fairly noncompeting groups, with little movement of labor from one to the other, a national wages policy which discriminates between them may be entirely feasible" (p. 522). But in the long run, professions must be chosen by economic agents, so that discriminatory wage policy will have a major impact on the choice of human capital. These difficulties extend even to lump sum transfers, a traditional redistribution scheme to preserve incentives, which B-F mention in footnote 11. The difficulty is that any lump sum tax which is not to affect incentives must be imposed before human capital decisions are made, but it beggars the imagination to suppose that the correct tax can be chosen at birth. If, however, the lump sum tax is imposed at a later time, then, in earlier times knowing that permanent income will be independent of human capital acquisition, one will avoid any such acquisition which entails nonpecuniary costs. This will presumably lead to underinvestment in human capital and loss of potential national income. Thus, schemes such as the lump sum tax which seem feasible in principle for simple exchange economies entail serious drawbacks in dynamic economies where human capital is a factor in production.

Finally, we must note that the wage discrimination scheme and similar devices are not incentive compatible. The revelation mechanism, by offering individuals differing wages and observing their responses in order to formulate a discriminatory set of wages,

[1]We assume that in the long run one would want to equalize not incomes, but rather the present values of income streams less pecuniary costs of generating these incomes.

would lead individuals to misrepresent their true labor-leisure preferences in order to benefit themselves. In such schemes, not only do people lack incentives to acquire human capital but they are given every incentive not to accurately report the information required in designing the scheme.

III. Summary

Baumol and Fischer argued that tax-transfer schemes which lead to income equality can do so only if incomes are zero. We have shown that result is true only when interpreted in a narrow and somewhat arbitrary manner. They have also claimed that discriminatory wages can achieve equality. The contrast in their results depends not on the difference between taxes and wage discrimination, as their exposition implies, but rather on the amount of discretion and information available to policy makers. In the tax schemes, taxes are allowed to vary only with incomes, but in the wage schemes, wages can vary with each individual, account being taken of his other characteristics. It is this difference which leads to the B-F results. Moreover, we also argue that too much is claimed for wage discrimination or related schemes. If we consider the long run so that human capital decisions are endogenous, then even an ideal lump sum tax scheme and a fortiori any other scheme which equalizes incomes will remove incentives to invest in human capital, unless abilities can be determined ab initio. Also, mechanisms suggested by B-F to ascertain wage schedules are themselves not incentive compatible, for they would lead individuals to misrepresent their true labor supply elasticities. We conclude that B-F have performed a valuable service in showing that tax-transfer schemes to equalize income are hardly feasible, but they may have mislead policymakers into thinking that alternative policies would prove any more feasible.

Appendix

We sketch the proof that with three or fewer persons, when incomes can be equalized for typical cases, they can be equalized for all closely similar cases. We suppose that a manifold structure has been put on A, the space of individual preference characteristics. For persons 1 and 2 with characteristics a_1 and a_2, then as noted in the text the local condition for income equalization is that

$$\text{(A1)} \quad \frac{MRS_1}{w_1}(y-t, v_1) = \frac{MRS_2}{w_2}(y-t, v_2) = (1-t').$$

Define

$$\text{(A2)} \qquad \rho: A \times A \times R^2 \to R^2$$

where

$$\text{(A3)} \quad \rho_{(a_1, a_2)}(y, t) = \frac{MRS_1}{w_1}(y-t, v_1(y)) \times \frac{MRS_2}{w_2}(y-t, v_2(y))$$

with

$$\text{(A4)} \qquad v_i(y) = \frac{y - w_i r^*}{-w_i}$$

so that the condition we need is that $\rho_{(a_1, a_2)}$ be transversal to the diagonal $\Delta R^2 \subset \{(x, x) \in R^2\}$ for some a_1, a_2. The text indicated how a typical example (a_1', a_2') that will obey this condition may be constructed. Then by an appropriate form of the transversal isotopy theorem (see R. Abraham and J. Robbin, p. 51), for all nearby (a_1, a_2) we have that $\rho^{-1}_{(a_1, a_2)}(\Delta)$ will be isotopic to $\rho^{-1}_{(a_1', a_2')}(\Delta)$ and so income equalization will continue to be possible.

Now Δ is of codimension 1 and so $\rho^{-1}_{(a_1, a_2)}(\Delta)$ will be of dimension 1 for two persons. By the same reasoning, for three persons $\rho^{-1}_{(a_1, a_2, a_3)}(\Delta)$ is of dimension 0 and for four or more persons the results fail to extend.

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The Output Distribution Frontier: Reply

By WILLIAM J. BAUMOL AND DIETRICH FISCHER*

Donald Keenan and Paul Rubin have raised a number of interesting points in their comment. Our main difference with them is that they tend to claim to disagree with us on issues on which our views are essentially the same as theirs. In addition, there are several matters of detail on which we must disagree.

Keenan and Rubin are technically correct in pointing out that a discriminatory tax rate can achieve what discriminatory wage rates can. But it is hard to imagine political acceptance of discriminatory tax rates as contrasted with differences in wage rates for different professions. But let us emphasize again that the discriminatory wage program was *not* formulated by us as a serious proposal, but as a demonstration that nondiscriminatory taxes and transfers do not exhaust the relevant set of policies. The discriminatory tax proposal, then, is fully in line with our view that additional candidate programs merit formulation.

We also agree that a policy of discriminatory wage rates requires a great deal of information. It is clear, as we stressed, that it is impossible to provide all the required observations on individual's utility functions. Nevertheless, a trial and error approach may be able to yield wage rates which reduce gross inequalities without an excessive loss of output, particularly if one deals only with large *groups* of workers and not individual by individual.

It is, of course, true that in economies with no more than three individuals special cases can be constructed in which a tax scheme happens to be able to achieve income equality without reducing output to zero. But what we show is that no tax scheme can *guarantee* equal incomes for arbitrary utility functions without reducing output to zero. In any event the case of interest in reality is, of course, that involving large numbers of individuals.

Keenan and Rubin's argument that "$y_1 = y_2 = 0$ is not an efficient point in any case"...since "there exists a $y_1^* > 0$, $y_2^* > 0$ dominating the origin" (p. 798) is based on a misunderstanding. The efficient frontier here is the set of points removed as far as possible from the origin on all rays of the form $y_2 = ky_1$, for $0 \leq k < \infty$. What we have shown is that generally for $k = 1$, that is, with perfect equality, the only feasible point intersecting that ray is the origin. The output distribution frontier calculated from a numerical example in the appendix, depicted in our Figure 9, shows that clearly. Keenan and Rubin's claim that we have ignored financial feasibility of the transfer scheme is incorrect. Throughout the analysis, we have assumed that the sum of all transfer payments is equal to the sum of tax revenues.

Keenan and Rubin's final point, on the issue of incentive-compatible information gathering schemes, is well taken. We raised that problem in our concluding section. Discrimination *will* cause some loss in terms of human capital formation, and its size cannot be determined a priori. The magnitude of the phenomenon can easily be exaggerated. People are influenced by their abilities and inclinations when choosing a profession, and not by pecuniary incentives alone. How great such an effect is likely to be is an issue for empirical investigation and cannot be settled by prejudgment.

*Princeton and New York Universities, and New York University, respectively.

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D. Keenan and P. H. Rubin, "The Output Distribution Frontier: Comment," *Amer. Econ. Rev.*, Sept. 1981, *71*, 796–99.

Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations

By PETER E. KENNEDY*

A recent note in this journal by Robert Halvorsen and Raymond Palmquist pointed out that empirical studies using a semilogarithmic functional form with dummy variables had misinterpreted the estimates of the coefficients of the dummy variables. For $\hat{c}$, the estimate of a dummy variable coefficient c, it has been common practice to estimate the percentage effect of that dummy variable on the variable being explained by $100\hat{c}$. Halvorsen and Palmquist show that $\hat{c}$ is in fact an estimate of $c = ln(1+g)$ where $100g$ is the correct measure of the percentage impact of the dummy variable on the variable being explained.

Unfortunately, Halvorsen and Palmquist address only the question of the relationship between c and g, ignoring the important problem of how $\hat{c}$ should be used to estimate g. They implicitly lead readers to believe that g should be estimated by $\hat{g} = exp(\hat{c}) - 1$, a biased estimator. This can be defended on the grounds that if $\hat{c}$ is a consistent estimate of c then $\hat{g}$ will be a consistent estimate of g; for those willing to defend estimates on asymptotic grounds, however, this estimate may not be acceptable.

Suppose, as is customary, that the error term in the original specification is lognormally distributed, and that $\hat{c}$ is an unbiased estimate of c. Then as noted by Arthur Goldberger, $E\,exp(\hat{c}) = exp(c + \frac{1}{2}V(\hat{c}))$ where $V(\hat{c})$ is the variance of $\hat{c}$. This suggests estimating $exp(c)$ by $exp(\hat{c} - \frac{1}{2}\hat{V}(\hat{c}))$ where $\hat{V}(\hat{c})$ is an estimate of the variance of $\hat{c}$. This implies an estimate for g of

$$g^* = exp\left(\hat{c} - \frac{1}{2}\hat{V}(\hat{c})\right) - 1$$

which, although it is still biased, has less bias than $\hat{g}$. For $\hat{c}$ positive, using g^* will reduce the disparity between the estimates of c and g as implied by Table 1 of Halvorsen and Palmquist.

In particular, Halvorsen and Palmquist report that the result of Eric Hanushek and John Quigley that a postgraduate degree increases the wages of a black worker by 64 percent is incorrect and should in fact be 90 percent. The estimation procedure presented here suggests that this effect should be estimated as 89 percent. Although in this example the difference between Halvorsen and Palmquist's biased estimate and the alternative suggested in this note is not large, for situations in which the variance of $\hat{c}$ is substantial, there could be a considerable difference between these two estimates.

*Simon Fraser University. My thanks to Robert Halvorsen and Raymond Palmquist for helpful comments.

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A. S. Goldberger, "The Interpretation and Estimation of Cobb-Douglas Functions," *Econometrica*, July-Oct. 1968, *35*, 464–72.

R. Halvorsen and R. Palmquist, "The Interpretation of Dummy Variables in Semilogarithmic Equations," *Amer. Econ. Rev.*, June 1980, *70*, 474–75.

E. A. Hanushek and J. M. Quigley, "Implicit Investment Profiles and Intertemporal Adjustments of Relative Wages," *Amer. Econ. Rev.*, Mar. 1978, *68*, 67–79.

NOTES

NINETY-FOURTH ANNUAL MEETING OF THE AMERICAN ECONOMIC ASSOCIATION

Washington, D.C., December 27–30, 1981

Preliminary Announcement of the Program

Sunday, December 27, 1981

10:00 A.M. EXECUTIVE COMMITTEE MEETING

Monday, December 28, 1981

8:00 A.M. GOVERNMENT ECONOMIC POLICY ASSESSMENT: THE LABOR MARKET*
Presiding: RAY MARSHALL, University of Texas-Austin
Papers: ORLEY C. ASHENFELTER, Princeton University
Employment Statistics—The Interaction of Economics and Policy
DANIEL S. HAMERMESH, Michigan State University
Does What Economists Know About Unemployment Insurance Make Any Difference?
RICHARD B. FREEMAN, Harvard University
Do Study Commissions Have Any Effect? The Case of the Minimum Wage
Discussants: ALBERT E. REES, Alfred P. Sloan Foundation
ISABEL V. SAWHILL, The Urban Institute

8:00 A.M. EMPIRICAL STUDIES OF TRADE AND THE EFFECTS OF TRADE POLICY
Presiding: INGO WALTER, New York University
Papers: MAURÍCIO BARATA DE PAULA PINTO, University of São Paulo
Fast Growing Exports: An Appraisal of the Brazilian Experience
T. BAYARD, K. JOHNSON, AND J. ORR, U.S. Department of Labor
The Distributional Impact of U.S. Trade Restrictions
ALICIA MULLOR-SEBASTIÁN, International Monetary Fund
The Product-Cycle Theory: Empirical Evidence
Discussants: KEITH MASKUS, University of Colorado
JOHN MUTTI, University of Wyoming

8:00 A.M. THE PRODUCTIVITY SLOWDOWN
Presiding: J. R. NORSWORTHY, U.S. Bureau of Labor Statistics
Papers: THOMAS G. WOODWARD, U.S. General Accounting Office
Narrowing Down the Possible Sources of the Productivity Slowdown
ANDREW SHARPE, Champlain Regional College
A Disaggregated Analysis of the Productivity Slowdown in Canada
GORDON C. WINSTON, Williams College
Investment and the Utilization of Capital: A Supply-Side Lesson from the Developing Countries
Discussants: CHARLES HOLTON, The Urban Institute
ERNST BERNDT, Massachusetts Institute of Technology

8:00 A.M. MARKET AND NON-MARKET INTERACTION UNDER ASYMMETRIC INFORMATION
Presiding: MILTON HARRIS, Northwestern University
Papers: CHESTER SPATT, Carnegie-Mellon University
An Intertemporal Model of Sales
DAVID SAPPINGTON, University of Michigan
Informational Asymmetry Between Principal and Agent
DANIEL F. SPULBER, Brown University
Spatial Competition with Nonlinear Pricing
Discussants: RAYMOND CHIANG, University of Florida
EDWARD GREEN, California Institute of Technology

8:00 A.M. EMPLOYMENT IMPLICATIONS OF THE CHANGING INDUSTRIAL BASE
Presiding: EILEEN COLLINS, National Science Foundation
Papers: EILEEN APPLEBAUM, Temple University
Employment Implications of the High-Tech Strategy for Reindustrialization
FAYE DUCHIN, New York University
Effects of Technical Change on Employment
JAMES JONDROW, ROBERT LEVY, AND LOUIS JACOBSON, Center for Naval Analyses
Labor Adjustment to Technical Change in Steel and Steel-Related Industries
JOHN VROOMAN, University of Utah
Technology and Labor Market Segmentation
Discussants: RONALD KUTSHER, U.S. Bureau of Labor Statistics
CAROL JUSENIUS, National Commission for Employment Policy

8:00 A.M. REGULATION OF FINANCIAL MARKETS: PRINCIPLES AND APPLICATIONS (Joint Session with the American Finance Association)
Presiding: WILLIAM L. SILBER, New York University
Papers: KENNETH D. GARBADE AND WILLIAM L. SILBER, New York University
Defining and Monitoring Best Execution in Financial Markets
HENDRICK S. HOUTHAKKER, Harvard University
Regulating Domination and Control of Financial Markets
ALFRED E. OSBORNE, University of California-Los Angeles
Rule 144 Volume Limitations and the Sale of Restricted Stock in the Over-the-Counter Market
Discussants: SEYMOUR SMIDT, Cornell University
FRANKLIN R. EDWARDS, Columbia University
AVNER KALAY, New York University

8:00 A.M. DYNAMICS OF THE WORLD FOOD SITUATION (Joint Session with the American Agricultural Economics Association)
Presiding: T. KELLY WHITE, U.S. Department of Agriculture
Papers: JOHN MELLOR, International Food Policy Research Institute
Third-World Development: Implications for Food and Poverty Situations
PADMA DESAI, Columbia University
Soviet Grain Import Demands for the 1980's
ANTHONY TANG, Vanderbilt University
Mainland China as a Factor in the World Food Situation
Discussants: CHARLES LIU, U.S. Department of Agriculture
PAN YOUTOPOLOUS, Stanford University

8:00 A.M. FEDERAL HEALTH PROGRAMS IN THE FACE OF BUDGET CUTBACKS (Joint Session with Health Economics Research Organization)
Presiding: DONALD E. YETT, University of Southern California
Papers: JESSIE S. HIXSON, U.S. Department of Health and Human Services
Budget Retrenchment and Health Manpower: Anticipated Effects on Medical, Dental, and Nursing School Enrollments
CHARLES R. LINK, University of Delaware, STEPHEN H. LONG, Syracuse University, AND RUSSEL F. SETTLE, University of Delaware
Effects of Medicaid Cutbacks on Access to Health Care Services
BARBARA H. KEHRER, Mathematica Policy Research
Federal Budget Cuts and the National Health Service Corps: Impact in Rural Areas
Discussants: PAUL FELDSTEIN, University of Michigan
ROGER REYNOLDS, American Medical Association
JACK HADLEY, The Urban Institute

8:00 A.M. NATURAL RESOURCES PRICES AND SCARCITY (Joint Session with Association of Environmental and Resource Economists)
Presiding: GEOFFREY HEAL, University of Essex
Papers: ANTHONY FISHER, University of California-Berkeley
Exploration and Scarcity: An Analysis of the Adequacy of Natural Resources
GEOFFREY HEAL, University of Essex, AND V. KERRY SMITH, University of North Carolina
An Econometric Evaluation of Long-Run Movements of Mineral Prices
GRACIELA CHICHILNISKY, Columbia University
Oil Prices, Industrial Prices, and Output: A General Equilibrium Macro Model

10:15 A.M. MACROECONOMIC POLICY IN THE OPEN ECONOMY*
Presiding: MICHAEL MUSSA, University of Chicago
Papers: MAURICE OBSTFELD, Columbia University
Can We Sterilize? Theory and Evidence
ROBERT FLOOD, University of Virginia
The Scope for Activism in the Open Economy
JEFFREY SACHS, Harvard University
Stabilization Policies in the World Economy: Scope and Skepticism
Discussants: JOHN KAREKEN, University of Minnesota
PAUL KRUGMAN, Massachusetts Institute of Technology
ALLAN C. STOCKMAN, University of Rochester

10:15 A.M. QUANTIFYING THE ROLE OF GOVERNMENT IN THE ECONOMY*
Presiding: JOHN SHOVEN, Stanford University
Papers: GEORGE F. BREAK, University of California-Berkeley
Issues in Measuring the Level of Government Economic Activity
MICHAEL J. BOSKIN, Stanford University
Measuring the Government Deficit: Myths and Realities
Discussants: HENRY AARON, The Brookings Institution
JEREMY BULOW, Stanford University

10:15 A.M. RECENT DEVELOPMENTS IN MACROECONOMIC THEORY: IMPLICATIONS FOR GOVERNMENT'S ROLE*
Presiding: ROBERT J. GORDON, Northwestern University
Papers: EDMUND S. PHELPS, Columbia University
Is Monetarism Dead?
THOMAS J. SARGENT, University of Minnesota
Reconsidering Macroeconomics
PENTTI J. K. KOURI, New York University
Restoring Price Stability with Prosperity
Discussants: GEORGE L. PERRY, The Brookings Institution
ALAN S. BLINDER, Princeton University

10:15 A.M. THE ECONOMICS MAJOR: WHAT IT IS AND WHAT IT SHOULD BE*
Presiding: W. LEE HANSEN, University of Wisconsin-Madison
Paper: JOHN J. SIEGFRIED, Vanderbilt University
The Economics Major: Past and Present
Panel Discussion: WHAT THE MAJOR SHOULD BE
D. GALE JOHNSON, University of Chicago
ROBERT J. LAMPMAN, University of Wisconsin-Madison
BERNARD SAFFRAN, Swarthmore College
ROBERT M. SOLOW, Massachusetts Institute of Technology

10:15 A.M. ABBA LERNER: SIX DECADES OF DISTINCTION
Presiding: WILLIAM J. BAUMOL, New York University and Princeton University
Papers: IRVING SOBEL, Florida State University
The Early Lerner
WILLIAM BREIT, University of Virginia
Abba Lerner: The Middle Era
DAVID COLANDER, University of Miami
Abba Lerner and Post-Keynesian Economics
Discussants: LORIE TARSHIS, University of Toronto
WILLIAM J. BAUMOL, New York University and Princeton University

10:15 A.M. INTERNATIONAL TRANSFER OF TECHNOLOGY
Presiding: ALAN RAPOPORT, National Science Foundation
Papers: M. THERESE FLAHERTY, Harvard University
International Technology Transfer: Global Strategies and Government Policies in High-Technology Industries
IRVING B. KRAVIS, University of Pennsylvania and National Bureau of Economic Research, AND ROBERT E. LIPSEY, City University of New York and National Bureau of Economic Research
Technological Factors in the Overseas Activities of U.S. Firms
EDWIN MANSFIELD, University of Pennsylvania
International Technology Transfer: Rates, Benefits, Costs, and Public Policy

Discussants: GARY HUFBAUER, Georgetown Law Center
SUMIYE OKUBO, GTE Laboratories
DAVID WALTERS, Office of the U.S. Trade Representative

10:15 A.M. LONGITUDINAL DATA BANKS: CONTRIBUTIONS TO THEORY AND POLICY
Presiding: HERBERT S. PARNES, Rutgers University
Papers: MICHAEL E. BORUS, Ohio State University
An Inventory of Longitudinal Data Sets and their Uses
LOLA M. IRELAN AND KAREN SCHWAB, U.S. Social Security Administration
Theoretical and Policy-Related Findings from the Social Security Administration's Retirement History Study
GREG J. DUNCAN AND JAMES N. MORGAN, University of Michigan
Longitudinal Lessons from the Panel Study of Income Dynamics
Discussants: DUANE E. LEIGH, Washington State University
JONATHAN LANE, Westminster, Massachusetts
JOSEPH F. QUINN, Boston College

10:15 A.M. REASSESSMENT OF PROPOSALS FOR ECONOMIC REFORM IN PUBLIC UTILITIES (Joint Session with the Transportation and Public Utilities Group of the AEA)
Presiding: JOHN C. SPYCHALSKI, Pennsylvania State University
Papers: HARRY M. TREBING, Michigan State University
A Critique of the "New Competition" in Telecommunications as a Surrogate for Regulation
WILLIAM G. SHEPHERD, University of Michigan
Price Structures in Electricity
EDWARD W. ERICKSON, North Carolina State University-Raleigh
Impact of Field Price Deregulation in the Natural Gas Industry
Discussants: CHARLES A. ZIELINSKI, Washington, D.C.
DAVID S. SCHWARTZ, Bethesda, Maryland

10:15 A.M. THE STRUCTURE OF SECURITIES MARKETS: REGULATORY MANDATES AND PRIVATE INCENTIVES (Joint Session with the American Finance Association)
Presiding: KENNETH D. GARBADE AND WILLIAM L. SILBER, New York University
Panelists: J. KEVIN KENNY, J. J. Kenny and Co., Inc.
WILLIAM KIDDER, Bill Kidder Reports, Inc.
JOHN H. HODGES, JR., National Association of Securities Dealers
GEORGE SIMON, Securities and Exchange Commission
DONALD KITTEL, New York Stock Exchange

10:15 A.M. MONETARY DYNAMICS AND CONTROL (Joint Session with Society of Economic Dynamics and Control)
Presiding: ALFRED L. NORMAN, University of Texas-Austin
Papers: P. A. V. B. SWAMY AND P. A. TINSLEY, Board of Governors of the Federal Reserve System
Noisy Transmission Channels in a Quarterly Policy Model
A. L. NORMAN, University of Texas-Austin, AND P. A. TINSLEY, Board of Governors of the Federal Reserve System
On the Stochastic Control of Large Nonlinear Econometric Models
WILLIAM A. BARNETT, PAUL A. SPINDT, AND EDWARD K. OFFENBACHER, Board of Governors of the Federal Reserve System
The Empirical Properties of Divisia Monetary Indexes
MASANAO AOKI, University of California-Los Angeles
Dynamic Distributional Effects of Monetary Instruments in a Three-Country Model of the World Under a Flexible Exchange Rate Regime
Discussants: CARL CHRIST, Johns Hopkins University
ART HAVENNER, University of California-Davis

12:30 P.M. JOINT LUNCHEON WITH THE AMERICAN ECONOMIC ASSOCIATION AND THE AMERICAN FINANCE ASSOCIATION
Presiding: GARDNER ACKLEY, University of Michigan, AND HARRY MARKOWITZ, IBM
Speaker: (To be announced)

2:00 P.M. GOVERNMENT AND THE AGING*
Presiding: HENRY AARON, The Brookings Institution
Papers: RICHARD BURKHAUSER, Vanderbilt University, AND JOHN A. TURNER, U.S. Department of Labor
Labor-Market Experience of the Almost Old and the Implications for Income Support
BARBARA TORREY, U.S. Office of Management and Budget
The Implications of an Aging Population for the Federal Budget
JOHN SHOVEN, Stanford University
The Consequences of Inflation for the Aged and the Implications for Public Policy
Discussants: KIM CLARK, Harvard University
ROBERT REISCHAUER, The Urban Institute
SUSAN WACHTER, University of Pennsylvania

2:00 P.M. MODELLING AND MEASURING THE COSTS AND BENEFITS OF GOVERNMENT CONSTRAINTS*
Presiding: RICHARD SCHMALENSEE, Massachusetts Institute of Technology
Papers: LEWIS PERL AND FREDERICK DUNBAR, National Economic Research Associates
Cost-Effectiveness and Cost-Benefit Analysis of Air Quality Regulations
ALBERT NICHOLS, Harvard University
The Costs and Benefits of Regulating Airborne Benzene
JERRY HAUSMAN AND PAUL JOSKOW, Massachusetts Institute of Technology
Evaluating the Effects of Energy Efficiency Standards for Appliances
Discussants: LESTER LAVE, The Brookings Institution
MARVIN KOSTERS, The American Enterprise Institute
W. DAVID MONTGOMERY, Resources for the Future, Inc.

2:00 P.M. IN HONOR OF ARTHUR OKUN*
Presiding: JAMES TOBIN, Yale University
Papers: LESTER THUROW, Massachusetts Institute of Technology
Government and Income Distribution
RICHARD LIPSEY, Queen's University
Government and Inflation
CHARLES SCHULTZE, The Brookings Institution and University of Maryland
The Role and Responsibility of the Economist in Government
Discussants: HAROLD W. WATTS, Columbia University
HENRY WALLICH, Board of Governors of the Federal Reserve System
HERBERT STEIN, University of Virginia
ALICE RIVLIN, Congressional Budget Office

2:00 P.M. LIMITS ON THE SIZE AND GROWTH OF GOVERNMENT*
Presiding EDWARD GRAMLICH, University of Michigan
Papers: ROBERT P. INMAN, University of Pennsylvania
Perspectives on Tax Limitation
PERRY SHAPIRO AND JON SONSTELIE, University of California-Santa Barbara
Did Proposition 13 Slay the Leviathan?
Discussants: GEOFFREY BRENNAN, Virginia Polytechnic Institute and State University
ANDREW RESCHOVSKY, Tufts University
HELEN LADD, Harvard University

2:00 P.M. RELIABILITY AND REPLICATION IN APPLIED ECONOMIC RESEARCH: A SYMPOSIUM (Joint Session with the Econometric Society)
Panel: JAN KMENTA, University of Michigan
KARL BRUNNER, University of Rochester
VERNON L. SMITH, University of Arizona
JAMES J. HECKMAN, University of Chicago
ROBERT J. GORDON, Northwestern University
LAWRENCE R. KLEIN, University of Pennsylvania
JEFFREY G. WILLIAMSON, University of Wisconsin-Madison
JACOB FRENKEL, University of Chicago
ZVI GRILICHES, Harvard University

2:00 P.M. WORK ALTERNATIVES TO WELFARE
Presiding: LARRY ORR, U.S. Department of Labor
Papers: RANDALL BROWN AND CHARLES MALLER, Mathematica Policy Research, AND ROBERT MOFFIT,
Rutgers University
Participation in the Employment Opportunity Pilot Projects
EDWARD CAVIN AND REBECCA MAYNARD, Mathematica Policy Research
Welfare Impacts of the Employment Opportunity Pilot Projects
JOHN BISHOP, Institute for Research on Poverty, AND GEORGE FARKAS, Abt Associates
Subsidized Employment in the Public and Private Sectors: Evidence from Employer Data
Discussants: PAULA ENGLAND, University of Texas-Dallas
CHARLES L. SKORO, Rutgers University

2:00 P.M. IMPORT RESTRAINTS AND REINDUSTRIALIZATION
Presiding: WILLIAM G. SHEPHERD, University of Michigan
Papers: JOEL B. DIRLAM, University of Rhode Island, AND HANS MUELLER, University of Tennessee-Murfreesboro
The Steel Industry
WALTER ADAMS, Michigan State University
The Automobile Industry
Discussants: BELA GOLD, Case-Western Reserve University
PETER ECKSTEIN, United Automobile Workers
PHILIP H. TRESIZE, The Brookings Institution

2:00 P.M. EXTERNAL FINANCING OF ECONOMIC DEVELOPMENT
Presiding: JOHN P. LEWIS, Princeton University
Papers: RICARDO MARTIN AND MARCELO SELOWSKY, World Bank
Energy Prices, Substitution, and Optimal Borrowing: An Analysis of Adjustment in Oil Importing Countries
DAVID BIGMAN, Hebrew University of Jerusalem
Food Aid and Food Distribution Programs
CHI SCHIVE, National Taiwan University, AND BADIUL A. MAJUMDAR, National Aeronautics and Space Administration
Direct Foreign Investment and Linkage Effects
Discussants: PETER HELLER, International Monetary Fund
JEROME WELLS, University of Pittsburgh

2:00 P.M. THEORETICAL ISSUES IN FUTURES TRADING
Presiding: CHARLES DALE, U.S. Department of Commerce
Papers: RONALD BRITTO, State University of New York-Binghamton and Universität Bonn
Futures Markets and the Supply of Storage
RONALD W. ANDERSON, Columbia University
Reconsidering the Determinants of Futures Price Volatility
THOMAS J. O'BRIEN AND PETER M. SCHWARZ, University of North Carolina-Charlotte
Ex Ante Evidence of Backwardation/Contango in Commodity Futures Prices
Discussants: GEORGE M. VON FURSTENBERG, International Monetary Fund
RICHARD W. LANG, Federal Reserve Bank of Philadelphia
JOHN F. WILSON, Board of Governors of the Federal Reserve System

2:00 P.M. MODELS OF FIRM BEHAVIOR UNDER REGULATORY CONSTRAINT
Presiding: SAM PELTZMAN, University of Chicago
Papers: JOHN T. TSCHIRHART, University of Wyoming
A Theory of Electric Power Pooling
JOHN E. KWOKA, JR., Northwestern University
The Behavior of Auto Firms under the Fuel Economy Constraint
EUGENE KROCH, Columbia University
Implications of Energy-Environmental Policy for Economic Welfare
Discussants: PETER COUGHLIN, Carnegie-Mellon University
MARGO THORNING, U.S. Department of Energy

2:00 P.M. RATIONING DEVICES FOR MEDICAL CARE (Joint Session with Health Economics Research Organization)
Presiding: ROBERT B. HELMS, U.S. Department of Health and Human Services
Papers: JOSEPH P. NEWHOUSE, The Rand Corporation
The Impact of Cost Sharing: Results from the Rand Health Insurance Experiment
GAIL R. WILENSKY, LOUIS F. ROSSITER, AND AMY K. TAYLOR, National Center for Health Service Research
The Role of Money and Time in the Demand for Medical Care
RICHARD M. SCHEFFLER, George Washington University
Deductibles, Coinsurance, and the Demand for Medical Care: Evidence from the U.M.W. Plan
Discussants: JUDITH LAVE, Health Care Financing Administration
VICTOR FUCHS, Stanford University and National Bureau of Economic Research
NELDA MCCALL, SRI International

8:00 P.M. RICHARD T. ELY LECTURE*
Presiding: GARDNER ACKLEY, University of Michigan
Speaker: GEORGE J. STIGLER, University of Chicago
(Title to be announced)

Tuesday, December 29, 1981

8:00 A.M. THE GLOBAL COMMONS I: COSTS AND CLIMATIC EFFECTS* (Joint Session with American Association for the Advancement of Science and the Association of Environmental and Resource Economists)
Presiding: ROGER BOLTON, Williams College
Papers: WILLIAM NORDHAUS, Yale University
Carbon Dioxide Viewed in an Optimal Control Framework
MARTIN BAILEY, University of Maryland
Risks, Costs, and Benefits of Fluorocarbon Regulation
RALPH D'ARGE, WILLIAM SCHULZE, AND DAVID BROOKSHIRE, University of Wyoming
Climate and Carbon Dioxide: An Economic-Ethical Perspective
Discussants: WILLIAM KELLOGG, National Center for Atmospheric Research
JOHN CUMBERLAND, University of Maryland
GLENN LOURY, University of Michigan

8:00 A.M. ANTI-INFLATION POLICIES AND THE PROBLEM OF CREDIBILITY*
Presiding: CHARLES L. SCHULTZE, The Brookings Institution and University of Maryland
Papers: JOHN B. TAYLOR, Princeton University
Establishing Credibility: A Rational-Expectations Viewpoint
THOMAS C. SCHELLING, Harvard University
Establishing Credibility: Strategic Considerations
VAL L. KOROMZAY, Organization for Economic Cooperation and Development
Credibility and Demand Restraint: Evidence from France and Germany
Discussants: WILLIAM FELLNER, American Enterprise Institute
JEFFREY SACHS, Harvard University

8:00 A.M. MICROECONOMICS RECONSIDERED*
Presiding: F. THOMAS JUSTER, University of Michigan
Papers: HARVEY LEIBENSTEIN, Harvard University
The Prisoner's Dilemma in the Invisible Hand: An Analysis of Productivity Growth within the Firm
RICHARD P. NATHAN, Princeton University, AND V. LANE RAWLINS, Washington State University
Factors that Influence the Execution and Character of Government Programs
RUTH P. MACK, Institute of Public Administration
"Optimizing" in Households: A Behavioral Theory
Discussants: PETER ROSSI, University of Chicago
RICHARD G. CYERT, Carnegie-Mellon University

8:00 A.M. IMPLICATIONS OF FORMAL THEORIES OF GOVERNMENT*
Presiding: MANCUR OLSON, JR., University of Maryland
Papers: WILLIAM NISKANEN, Council of Economic Advisers
What (If Anything) Do We Know about the Growth of Government?
KENNETH SHEPSLE AND BARRY WEINGAST, Washington University
Structure Induced Equilibrium, Legislative Choice, and Public Policy

ALBERT NICHOLS AND RICHARD ZECKHAUSER, Harvard University
The Potential Efficiency of In-Kind Transfers
Discussants: EUGENE SMOLENSKY, University of Wisconsin
SUSAN ROSE-ACKERMAN, Yale University
PETER ARANSON, Emory University

8:00 A.M. MEASURING THE IMPACT OF INDUSTRIAL POLICY ON PRODUCTIVITY AND GROWTH
Presiding: F. GERARD ADAMS, University of Pennsylvania
Papers: LAWRENCE R. KLEIN AND MENAHEM PRYWES, University of Pennsylvania
Industrial Policy Impacts on Productivity and Growth in Production Functions
F. GERARD ADAMS AND VIJAYA G. DUGGAL, University of Pennsylvania
Macro Model Simulations of Industrial Policy Strategies
ROBERT EISNER AND STEVEN BENDER, Northwestern University
Differential Impacts of Tax Incentives for Investment
Discussants: LARRY DILDINE, U.S. Department of Treasury
ROBERT DROITSCH, U.S. Department of Labor
ROBIN SICKLES, University of Pennsylvania

8:00 A.M. NEW INSIGHTS ON THE ECONOMIC STATUS OF THE AMERICAN PEOPLE
Presiding: RICHARD RUGGLES, Yale University
Papers: CHARLES A. LININGER AND THOMAS CAMERON WHITEMAN, U.S. Department of Health and Human Services
The 1979 ISDP Research Panel: Scope, Coverage, and Data Reliability
MICHAEL TAUSSIG, Rutgers University, AND SHELDON DANZIGER, University of Wisconsin-Madison
A New View of Poverty Based on the 1979 ISDP/SIPP Research Panel
DANIEL RADNER, U.S. Department of Health and Human Services
The Joint Distribution of Wealth and Income
ROBERT FERBER, University of Illinois
Portfolio Composition of American Households
Discussants: EDWARD BUDD, Pennsylvania State University
MARTIN DAVID, University of Wisconsin-Madison
RICHARD RUGGLES, Yale University

8:00 A.M. POLITICAL AND ECONOMIC DETERMINANTS OF TRADE BARRIERS
Presiding: ANNE O. KRUEGER, University of Minnesota
Papers: ROBERT BALDWIN, University of Wisconsin-Madison
Political Economy of U.S. Import Policy
RONALD FINDLAY AND STANISLAW WELLISZ, Columbia University
Some Political Economy Aspects of Trade Restriction in the Presence of International Factor Mobility
J. M. FINGER, World Bank
Political Economy of Administered Protection
Discussants: JORGE BRAGA DE MACEDO, Princeton University
STEPHEN P. MAGEE, University of Texas-Austin
PATRICK MESSERLIN, University of Houston

8:00 A.M. MODELS OF FIRM BEHAVIOR AND MARKET STRUCTURE
Presiding: ANDREW W. POSTLEWAITE, University of Pennsylvania
Papers: RICHARD N. CLARKE, University of Wisconsin-Madison
Oligopoly as a Differential Game
DAVID E. MILLS, University of Virginia
Competitive Industry Structure with Output Fluctuation
JOHN M. CONNOR, U.S. Department of Agriculture
Food Product Proliferation: A Market Structure Analysis
Discussants: DONALD DEWEY, Columbia University
KWAN CHOI, University of Missouri-Columbia

8:00 A.M. REGULATION OF HOUSING MARKETS (Joint Session with American Finance Association)
Presiding: LAURENCE C. ROSENBERG, National Science Foundation
Papers: DWIGHT M. JAFFEE AND KENNETH T. ROSEN, Princeton University
Implications of the Demographic Aspects of Housing Demand
JAMES R. BARTH, MITCHELL RACHLIS, AND ANTHONY M. YEZER, George Washington University
Spatial Variation in the Variance of Housing Prices: Implications for Redlining Regulation
GEORGE J. BENTSON AND DAN HORSKY, University of Rochester
The Relation Between Mortgage Demand and Neighborhood Characteristics

Discussants: MARSHALL A. KAPLAN, Federal Home Loan Bank Board
PATRIC H. HENDERSHOTT, Purdue University
ANTHONY SANTOMERO, University of Pennsylvania

8:00 A.M. RECENT DEVELOPMENTS IN PUBLIC REGULATION (Joint Session with National Economic Association)
Presiding: ALFRED L. EDWARDS, University of Michigan
Papers: LUCY REUBEN, Duke University, AND JOHN COLE, University of North Carolina-Chapel Hil
Some Recent Developments in Bank Regulatory Activities
CONSTANCE RECHARD, U.S. Department of Transportation
Changing Directions in Air Transportation
WILHELMINA COOKE, Citizens Communication Association
Notes on Regulation in the Communications Industry

8:00 A.M. CONTRIBUTIONS TO THE HISTORY OF ECONOMIC THOUGHT (Joint Session with the History of Economics Society)
Presiding: WARREN J. SAMUELS, Michigan State University
Papers: SAMUEL HOLLANDER, University of Toronto
On the Substantive Identity of the Classical and Neoclassical Conceptions of Economic Organization
WILLIAM D. GRAMPP, University of Illinois-Chicago
A Reconsideration of Cantillon's *Essai*
KLAUS H. HENNINGS, University of Hannover
Economists and Engineers: The Influence of Engineers on the Formation of Neoclassical Economic Theory
Discussants: JOHN K. WHITAKER, University of Virginia
KAREN I. VAUGHN, George Mason University
VINCENT J. TARASCIO, University of North Carolina

10:15 A.M. THE GLOBAL COMMONS II: INSTITUTIONS AND DECISIONS* (Joint Session with American Association for the Advancement of Science and the Association of Environmental and Resource Economists)
Presiding: KENNETH BOULDING, University of Colorado
Papers: LESTER LAVE, The Brookings Institution
Mitigating Strategies for Carbon Dioxide Problems
MANCUR OLSON, JR., University of Maryland
Environmental Indivisibilities and Information Costs
THOMAS DOWNING AND ROBERT KATES, Clark University
The International Response to the Threat of Chlorofluorocarbons to Atmospheric Ozone
Discussants: ROGER NOLL, California Institute of Technology
THOMAS WALTZ, U.S. Department of Energy
MICHAEL GLANTZ, National Center for Atmospheric Research

10:15 A.M. LONGER-RUN DETERMINANTS OF THE ECONOMIC ROLE OF THE U.S. GOVERNMENT*
Presiding: BENJAMIN WARD, University of California-Berkeley
Papers: DOUGLAS NORTH, University of Washington
American Government Expenditures: A Historical Perspective
HERBERT GINTIS, University of Massachusetts-Amherst
The Expansion of the American State: An Interpretation
BENJAMIN WARD, University of California-Berkeley
American Government Expenditures: Some Comparative Hypotheses
Discussants: RICHARD SUTCH, University of California-Berkeley
RICHARD ROEHL, University of Michigan-Dearborn

10:15 A.M. POLITICAL OBSTACLES TO SUCCESSFUL ECONOMIC POLICIES*
Presiding: JAMES L. SUNDQUIST, The Brookings Institution
Papers: ALICE M. RIVLIN, Congressional Budget Office
The Political Economy of Budget Choices
ROGER D. PORTER, Harvard University
(Title to be announced)
(Third author and title to be announced)
Discussants: JOSEPH L. FISHER, Wilderness Society
HERBERT STEIN, University of Virginia

10:15 A.M. IMPERFECT COMPETITION AND PUBLIC POLICY*
Presiding: HAL R. VARIAN, University of Michigan
Papers: AVINASH DIXIT, Princeton University
Recent Developments in the Theory of Imperfect Competition
LOUIS WILDE AND ALAN SCHWARTZ, California Institute of Technology
Imperfect Information and Monopolistic Competition
RICHARD SCHMALENSEE, Massachusetts Institute of Technology
Antitrust and the New Industrial Economics
Discussants: DAVID SAPPINGTON, University of Michigan
ELIZABETH E. BAILEY, Civil Aeronautics Board
PETER STEINER, University of Michigan

10:15 A.M. FINANCIAL MARKETS, THE MONETARY MECHANISM, AND MONETARY POLICY (Joint Session with the American Finance Association)
Presiding: PAUL A. VOLCKER, Board of Governors of the Federal Reserve System
Papers: BENJAMIN M. FRIEDMAN, Harvard University
Money, Credit, Interest Rates, and Monetary Policy
FRANCO MODIGLIANI, Massachusetts Institute of Technology, AND LUCAS PAPADEMOS, Columbia University
Inflation, Financial Markets, and Monetary Policy
ANTHONY M. SANTOMERO AND JEREMY J. SIEGEL, University of Pennsylvania
Controlling Monetary Aggregates in a General Equilibrium Framework
DALE W. HENDERSON, Board of Governors of the Federal Reserve System
Exchange Rate Market Intervention Operations: Their Effects and Their Role in Financial Policy
Discussants: STANLEY W. BLACK, Vanderbilt University
PHILLIP CAGAN, Columbia University
CHRISTOPHER A. SIMS, University of Minnesota
JAMES L. PIERCE, University of California-Berkeley

10:15 A.M. POLICY PERSPECTIVES ON FINANCING ECONOMIC DEVELOPMENT (Joint Session with National Economic Association)
Presiding: ALEX WILLIAMS, University of Virginia
Papers: ALEXANDER KAFKA, International Monetary Fund
Exchange Rates Policy, Capital Movements, and the Finance of Development
ALEX WILLIAMS, University of Virginia
The Balance of Payments and the Measurement of Debt Capacity
NORMAN MILLER, University of Pittsburgh
A General Equilibrium Approach to Balance of Payments, with Focus on Developing Economies

10:15 A.M. CLUB THEORY AND APPLICATIONS
Presiding: JOHN TSCHIRHART, University of Wyoming
Papers: V. KERRY SMITH, University of North Carolina-Chapel Hill
Modeling the Economic Behavior of Private, "Public Interest" Groups
JOHN SORRENTINO, Temple University, AND DORRIE DELUCA, General Electric Company
On the Applicability of Club Theory: An Outer Space Allocation Example
TODD SANDLER AND JOHN TSCHIRHART, University of Wyoming
Pareto Efficiency and Heterogenous Club Membership
Discussants: LARRY S. EUBANKS, University of Oklahoma
ROGER SHERMAN, University of Virginia
ROBERT TOLLISON, Virginia Polytechnic Institute and State University

10:15 A.M. GOVERNMENT URBAN POLICIES
Presiding: EDWIN S. MILLS, Princeton University
Papers: PETER MIESZKOWSKI, University of Houston
Trends and Prospects in State-Local Government Finance
RAYMOND STRUYK, The Urban Institute
Government's Role in Housing: Back to Basics
PAUL COURANT, University of Michigan
Urban and Regional Impacts of Federal Economic Policies
Discussants: BRUCE HAMILTON, Johns Hopkins University
MAHLON STRASZHEIM, University of Maryland
WILLIAM OAKLAND, Tulane University

10:15 A.M. THE ECONOMICS OF ACADEMIC RETIREMENT
Presiding: W. LEE HANSEN, University of Wisconsin-Madison
Papers: W. LEE HANSEN AND KAREN C. HOLDEN, University of Wisconsin-Madison
Faculty Responses to Raising the Mandatory Retirement Age
KATHERINE H. HANSON, Consortium for Financing of Higher Education
Faculty Retirement in Changing Economic Conditions
FRANCIS P. KING, Teachers Insurance and Annuity Association
Mandatory Retirement and Private Pension Plans
Discussants: RICHARD V. BURKHAUSER, Vanderbilt University
CARL V. PATTON, University of Illinois
ARCHIE KLEINGARTNER, University of California-Berkeley

10:15 A.M. ASSESSING STABILITY AND TECHNOLOGICAL CHANGE IN THE FINANCIAL SECTOR
Presiding: HENRY C. WALLICH, Board of Governors of the Federal Reserve System
Papers: CHRISTOPHER F. BAUM, Boston College, AND E. P. SHEA Northeastern University
Assessing Financial Innovation in Response to the 1980 Monetary Reform Act
WILLIAM A. BARNETT, PAUL SPINDT, AND EDWARD OFFENBACHER, Board of Governors of the Federal Reserve System
Assessing the Stability of the Demand for Money Function with the New Divisia Monetary Aggregates
EVELYN F. CARROLL, Federal Reserve Bank of Minneapolis
Technological Change in the Financial System–Where is the Paperless Society?
Discussants: GILLIAN GARCIA, University of California-Berkeley
CHRISTINE AMSLER, Michigan State University

10:15 A.M. THE STATE OF THE ART
Presiding: JACK BARBASH, University of Wisconsin
Papers: MARK PERLMAN, University of Pittsburgh
The Conflict Between Synthesis and Analysis in Economics
JOHN CULBERTSON, University of Wisconsin
Economics and Scientific Method
JACK BARBASH, University of Wisconsin
The Guilds of Academe: Economics a Case in Point
Discussant: LEONARD SILK, *The New York Times*

10:15 A.M. THE IMPACT OF STATE AND LOCAL TAXES
Presiding: ROBERT REISCHAUER, The Urban Institute
Papers: DONALD PHARES, University of Missouri-St. Louis
Who Pays State and Local Taxes?
DENNIS DETRAY AND JUDITH FENANDEZ, The Rand Corporation
Tax Burdens and Fiscal Change in Ten Cities
HOWARD CHERNICK, U.S. Department of Health and Human Services, AND ANDREW RESCHOVSKY, Tufts University
The Distributional Impact of Proposition 13: A Microsimulation Approach
Discussants: JEROME F. HEAVEY, Lafayette College
JAMES M. BICKLEY, U.S. Library of Congress

12:30 P.M. LUNCHEON IN HONOR OF NOBEL LAUREATE, LAWRENCE R. KLEIN
Presiding: WILLIAM J. BAUMOL, New York University and Princeton University
Speaker: (To be announced)

2:00 P.M. THE IMPACT OF PUBLIC PROGRAMS ON THE STATUS OF WOMEN*
Presiding: ELIZABETH E. BAILEY, Civil Aeronautics Board
Papers: NANCY BARRETT, American University
Political Obstacles to Economic Parity for Women
HELEN F. LADD, Harvard University
Equal Opportunity and the Availability of Mortgage Credit to Women
ANDREA BELLER, University of Illinois
Equal Opportunity Laws and the Entry of Women into Nontraditional Occupations
Discussants: CLAIR BROWN, University of California-Berkeley
JANET GOULET, Wittenberg University
ELLEN BUSSEY, Consultant and Arbitrator

2:00 P.M. MONETARY POLICY AND THE CHANGING MEANING OF MONEY* (Joint Session with American Finance Association)
Presiding: DONALD A. NICHOLS, University of Wisconsin-Madison
Papers: THOMAS MAYER, University of California-Davis
Financial Innovation: The Conflict Between Micro and Macro Optimality
GEORGE A. AKERLOF, University of California-Berkeley
The Short-Run Demand for Money: A New Look at an Old Problem
DONALD D. HESTER, University of Wisconsin-Madison
On the Adequacy of Policy Instruments and Information When the Meaning of Money is Changing
Discussants: ANDREW S. CARRON, The Brookings Institution
BRYCE HOOL, State University of New York-Stony Brook
RAYMOND E. LOMBRA, Pennsylvania State University

2:00 P.M. GOVERNMENT AND THE AUTOMOBILE*
Presiding: OWEN IRVINE, Wesleyan University
Papers: DAVID HARRISON, Harvard University, AND JOSÉ ANTONIO GOMEZ-IBANEZ, Council of Economic Advisers
The Role of Imports in the Automobile Industry's Problems
ROBERT CRANDALL, THEODORE KEELER, AND LESTER LAVE, The Brookings Institution
Economic Effects of Safety, Emissions, and Fuel-Economy Regulations on the Cost and the Value of Automobile Transportation
HOWARD GRUENSPECHT, Carnegie-Mellon University
New-Source Bias in Automobile-Emissions Regulation: An Analysis of Impacts and Alternatives
LAWRENCE WHITE, New York University
Automobile Emissions: Do Controls Really Work?
Discussants: WILLIAM A. NISKANEN, Council of Economic Advisers
GEORGE EADS, The Rand Corporation

2:00 P.M. BUDGETT AND TAX POLICY: A SYMPOSIUM
Presiding: JOSEPH A. PECHMAN, The Brookings Institution
Panelists: MARTIN FELDSTEIN, Harvard University and the National Bureau of Economic Research
ALICE M. RIVLIN, Congressional Budget Office
CHARLES L. SCHULTZE, The Brookings Institution and University of Maryland
MURRAY L. WEIDENBAUM, Council of Economic Advisers

2:00 P.M. EMPIRICAL ESTIMATION AND USE OF RISK PREFERENCES (Joint Session with American Agricultural Economics Association)
Presiding: VERNON EIDMAN, University of Minnesota
Papers: LINDON J. ROBISON, Michigan State University
An Appraisal of Estimation Methods that Use Response to Hypothetical Questions and Experimental Choices
RULON D. POPE, Texas A&M University
An Appraisal of Estimation Methods that Use Actual Economic Decisions
PETER B. R. HAZELL, International Food Policy Research Institute
Application of Risk Preference Estimates in Firm-Household and Agricultural Sector Models
Discussants: HANS P. BINSWANGER, World Bank
TERRY ROE, University of Minnesota

2:00 P.M. THE EFFECTS OF COMPETITION AND REGULATION ON THE HEALTH-CARE SECTION (Joint Session with the Health Economics Research Organization)
Presiding: DONALD E. YETT, University of Southern California
Papers: HAROLD S. LUFT AND SUSAN C. MAERKI, University of California-San Francisco
Effects of Competition by HMO's on Hospital Utilization
ALVIN E. HEADEN, JR., Blue Cross and Blue Shield Associations
The Impact of Certificate-of-Need Regulation on Hospital Investment
PHILIP FANARA, JR. AND WARREN GREENBURG, University of Maryland
The Impact of Competition on Blue Cross Risk Selection
Discussants: WILLIAM D. WHITE, University of Illinois-Chicago
DAVID S. SALKEVER, Johns Hopkins University
WILLIAM J. LYNK, Lexecon, Inc.

2:00 P.M. PROFESSIONAL OPPORTUNITIES FOR ECONOMISTS: PANEL DISCUSSION (Joint Session with Omicron Delta Epsilon)
Presiding: EGON NEUBERGER, State University of New York-Stony Brook
Panelists: ROGER P. MENDELS, University of Windsor
ROBERT REISCHAUER, The Urban Institute
CHARLES SIEGMAN, Board of Governors of the Federal Reserve System
LAURENCE J. BRAINARD, Bankers Trust Company

2:00 P.M. SYMPOSIUM ON AMERICAN ECONOMICS IN THE 1930'S AND 1940'S: THE RISE TO WORLD LEADERSHIP (Joint Session with the History of Economic Society)
Presiding: JOHN K. WHITAKER, University of Virginia
Panelists: WILLIAM J. FELLNER, American Enterprise Institute
GEORGE J. STIGLER, University of Chicago
MARK PERLMAN, University of Pittsburgh

2:00 P.M. TRADE POLICIES, LABOR MARKETS, AND ECONOMIC DEVELOPMENT
Presiding: RONALD I. MCKINNON, Stanford University
Papers: CARLOS E. SANTIAGO, Wayne State University
A "Dual-Dual" Framework of Labor Allocation and its Application to Puerto Rico
GEORGE C. GEORGIOU, George Washington University
Alternate Trade Strategies and Employment in Cyprus
IRA N. GANG, Cornell University
Labor Markets, Trade Policies, and the LDC Poor
JAE WAN CHUNG, George Mason University, AND UNGSUH K. PARK, Korea, International Economic Institute
Export Promotion, Cost of Production, and Economic Development
Discussants: JEFFREY S. HAMMER, University of California-San Diego
CARMEL CHISWICK, University of Illinois-Chicago

2:00 P.M. HISPANICS IN THE U.S. LABOR FORCE
Presiding: DANIEL H. SAKS, National Commission for Employment Policy
Papers: JOHN ABOWD, University of Chicago, AND MARK KILLINGSWORTH, Rutgers University
An Analysis of the Wages, Earnings, and Employment of Hispanics in the Federal and Private Sectors
GEORGE J. BORJAS, University of California-Santa Barbara
Do Blacks and Hispanics Compete in the Labor Market?
CORDELIA REIMERS, Princeton University
The Structure of Hispanic-American Wages: Implications for Policy
Discussants: BARRY CHISWICK, University of Illinois-Chicago
RONALD OAXACA, University of Arizona

2:00 P.M. MONETARY POLICY AND EXCHANGE RATES
Presiding: DEAN G. TAYLOR, State University of New York-Albany
Papers: MICHAEL CONNOLLY, University of South Carolina
Optimum Currency Pegs for Latin America
MICHAEL R. DARBY, University of California-Los Angeles and National Bureau of Economic Research, AND JAMES R. LOTHIAN, Citibank and National Bureau of Economic Research
Exchange Rate Systems and Trends in Inflation
ALAN C. STOCKMAN, University of Rochester and National Bureau of Economic Research
Exchange Rates and Real Effects of Monetary Policy
Discussants: ANTHONY M. LANYI, International Monetary Fund
MICHAEL T. MELVIN, Arizona State University

2:00 P.M. ECONOMICS OF BUSINESS FAILURE
Presiding: JOHN SHOVEN, Stanford University
Papers: MICHELLE D. WHITE, New York University
The Economics of Bankruptcy
ROBERT B. ARCHIBALD AND SAMUEL H. BAKER, College of William and Mary
The Macroeconomics of Business Failure
AKIO YASUHARA, Vanderbilt University
Convertible Bonds and the Wealth Redistribution from Bankruptcy
Discussants: LAWRENCE BLUME, University of Michigan
ALAN J. AUERBACH, Harvard University

8:00 P.M. PRESIDENTIAL ADDRESS
Presiding: W. ARTHUR LEWIS, Princeton University
Speaker: WILLIAM J. BAUMOL, New York University and Princeton University
(Title to be announced)

9:30 P.M. BUSINESS MEETING

Wednesday, December 30, 1981

8:00 A.M. GOVERNMENT AND HEALTH* (Joint Session with Health Economics Research Organization)
Presiding: VICTOR R. FUCHS, Stanford University and National Bureau of Economic Research
Papers: MICHAEL GROSSMAN, City University of New York Graduate School and National Bureau of Economic Research
Government and Health Outcomes
FRANK A. SLOAN, Vanderbilt University
Government and the Regulation of Hospital Care
GAIL R. WILENSKY, National Center for Health Services Research
Government and the Financing of Health Care
Discussants: JOSEPH P. NEWHOUSE, The Rand Corporation
ALLAN S. DETSKY, University of Toronto

8:00 A.M. IMPLEMENTING REGULATORY CHANGE: THREE CASE STUDIES*
Presiding: PAUL JOSKOW, Massachusetts Institute of Technology
Papers: BARRY WEINGAST, Washington University
Regulatory Discretion and Congressional Control as Sources of Policy Change at the FTC
JAN ACTON, The Rand Corporation
An Evaluation of Electric Utility Rate Reforms
ROGER NOLL, California Institute of Technology
Implementing Marketable Emissions Permits
Discussants: DAVID MCNICOL, Department of Energy
DAVID MONTGOMERY, Resources for the Future, Inc.
DOUGLAS WEBBINK, Federal Communications Commission

8:00 A.M. THE IMPACT OF REGULATION
Presiding: THOMAS GALE MOORE, The Hoover Institution
Papers: MACK OTT, Pennsylvania State University, AND AMY WALTON, California Institute of Technology
The Impact of Regulatory Uncertainty on Investment
ELI M. NOAM, Columbia University
A Model of Cable Television Channel Allocation
RICHARD E. SCHULER, Cornell University
The Consequences of Alternative Organizations of the Electric Utility Industry
Discussants: MYRON H. ROSS, Western Michigan University
LACY GLENN THOMAS, University of Illinois

8:00 A.M. STUDIES OF THE LOCAL IMPACT OF FEDERAL PROGRAMS
Presiding: MARTIN HOLMER, U.S. Department of Health and Human Services
Papers: SEMOON CHANG, University of South Alabama
Do Disaster Areas Benefit from Disasters?
PHILIP L. BURSTEIN, Abt Associates
The Social Value of Output from a Work Equity Project
HAYNES C. GODDARD, University of Cincinnati
The Economic Implications of Court-Ordered School Desegregation
A. H. STUDENMUND, Occidental College
The Free-Fare Transit Experiments
Discussants: CHARLES CLOTFELTER, Duke University
PHILLIP MOSS, Boston University

8:00 A.M. DISEQUILIBRIUM ANALYSIS FOR DEVELOPING ECONOMIES
Presiding: H. ROBERT HELLER, Bank of America

Papers: BELA BALASSA, Johns Hokins University and World Bank
Disequilibrium Analysis for Developing Countries: An Overview of Issues and Techniques
MAXWELL J. FRY, University of California-Irvine
Interest Rate Disequilibrium Analysis for Developing Economies
ANNE O. KRUEGER, University of Minnesota
Analyzing Disequilibrium Exchange Rate Systems in Developing Economies
VITO TANZI, International Monetary Fund
Disequilibrium in the Fiscal Sector of Developing Economies
Discussants: ROY BAHL, Syracuse University
RONALD I. MCKINNON, Stanford University

8:00 A.M. ASSESSING ITALIAN POSTWAR GROWTH
Presiding: GARDNER ACKLEY, University of Michigan
Papers: E. GRILLI, World Bank, J. A. KREGEL, Rijksuniversiteit Gronigen and Rutgers University, AN
P. SAVONA, Free University of Social Sciences, Rome
Terms of Trade and Italian Economic Growth: Accounting for Miracles
GIORGIO FUÀ, University of Ancona
The Italian Economy: Problems of Lagged Development
IGNAZIO MUSU AND PAOLO COSTA, University of Venice
Experiments with an Input-Output Model of the Italian Economy
Discussants: DONALD TEMPLEMAN, United States Department of Treasury
HOLLIS CHENERY, World Bank
FRANCO MODIGLIANI, Massachusetts Institute of Technology
GARDNER ACKLEY, University of Michigan

8:00 A.M. ECONOMICS OF HIGHER EDUCATION
Presiding: ARTHUR PADILLA, University of North Carolina and The Brookings Institution
Papers: DAVID A. GARVIN, Harvard University
Models of University Behavior
DAVID W. BRENEMAN, The Brookings Institution
The Labor Market for Doctorates: Issues for the 1980's
ARTHUR PADILLA, University of North Carolina and The Brookings Institution
The Public Sector and Private Higher Education
Discussants: DAVID S. BALL, North Carolina State University
JUNE O'NEILL, The Urban Institute

10:15 A.M. IMPACT OF REGULATION ON MONEY-MARKET INSTITUTIONS (Joint Session with American Financ Association)
Presiding: JACK GUTTENTAG, University of Pennsylvania
Papers: ANTHONY M. SANTOMERO AND JEREMY J. SIEGEL, University of Pennsylvania
A New Money and Banking Paradigm to Deal with Recent Financial Innovations
SUDIPTO BHATTACHARYA, Stanford University
Notes on Money and Banking with Moral Hazard and Taxation
PAUL F. SMITH, University of Pennsylvania
Structural Disequilibrium and the Banking Act of 1980

8:00 A.M. DATA AND THE PROVISION OF DATA
Presiding: IRVING KRAVIS, University of Pennsylvania
Papers: F. GERARD ADAMS, University of Pennsylvania
Revisions of the U.S. National Accounts: Implications for Forecasting and Policy
ROBERT P. PARKER, U.S. Department of Commerce
The Quality of the National Income and Product Accounts of the United States
CHARLES G. RENFRO, University of Kentucky
The Computer as a Factor of Production in Economic Data Provision and Research
Discussants: OTTO ECKSTEIN, Harvard University
E. PHILIP HOWREY, University of Michigan
ALBERT E. REES, Alfred P. Sloan Foundation

8:00 A.M. EXPERIMENTS IN VALUING PUBLIC GOODS (Joint Session with Association of Environmental and Resource Economists)
Presiding: WILLIAM J. BAUMOL, New York University and Princeton University

Papers: CHARLES PLOTT, California Institute of Technology
License to Pollute: Some Experimental Results
DAVID BROOKSHIRE AND WILLIAM SCHULTZE, University of Wyoming
National Parks and Beauty: A Test of Existence Value
ALAN RANDALL, University of Kentucky, AND GEORGE TOLLEY, University of Chicago
Revealing Willingness to Pay: The Effects of Experimental Formats
Discussants: VERNON SMITH, University of Arizona
RICHARD BISHOP, University of Wisconsin
GORDON TULLOCK, Virginia Polytechnic Institute and State University

10:15 A.M. PAY, PENSIONS, AND EMPLOYMENT IN GOVERNMENT*
Presiding: ROBERT W. HARTMAN, The Brookings Institution
Papers: FRANK S. LEVY, The Urban Institute
Sources of Growth in Local Government Employment
JOSEPH F. QUINN, Boston College
Pensions in the Public Sector
SHARON P. SMITH, Federal Reserve Bank of New York
Prospects for Reforming Federal Pay
Discussants: HARVEY GALPER, Advisory Commission on Intergovernmental Relations
BARBARA TORREY, U.S. Office of Management and Budget
ROBERT W. HARTMAN, The Brookings Institution

10:15 A.M. GOVERNMENT AND PRODUCTIVITY*
Presiding: RICHARD ZECKHAUSER, Harvard University
Papers: PETER K. CLARK, Board of Governors of the Federal Reserve System
Inflation and the Productivity Slowdown
DENNIS MUELLER, International Institute of Management and University of Maryland
The Political Consequences of a Decline in Productivity
MANCUR OLSON, JR., University of Maryland
The Political Economy of the Decline in Productivity
Discussants: ANTHONY DOWNS, The Brookings Institution
OLIVER WILLIAMSON, University of Pennsylvania

10:15 A.M. GOVERNMENT, FOOD, AND AGRICULTURE
Presiding: GORDON C. RAUSSER, University of California-Berkeley
Papers: COLIN LAWRENCE, Columbia University, AND ROBERT Z. LAWRENCE, The Brookings Institution
International Commodity Markets, Asset Markets, and Inflation
JOHN W. FREEBAIRN, Latrobe University
Governmental Intervention and Food Price Inflation
ROBERT E. JUST, GORDON C. RAUSSER, AND DAVID ZILBERMAN, University of California-Berkeley
The Distributional Effects of U.S. Agricultural Policy and the Role of Land Prices
Discussants: ROBERT J. GORDON, Northwestern University
CARL VAN DUYNE, Williams College
BRUCE GARDNER, University of Chicago

10:15 A.M. COMPARATIVE WAGE-PRICE BEHAVIOR
Presiding: DAVID COLANDER, University of Miami
Papers: WILLIAM G. DEWALD, WILLIAM GAVIN, DENNIS PETRUSKA, AND MITSURA TOIDA, Ohio State University
Inflation-Output Dynamics in Small Models of Germany, Italy, Japan, and the United States
JONG S. YOU, Algoma University College, AND JONG KEUN YOU, New Jersey Office of Economic Policy
An Estimation of Natural Unemployment Rates in Canada, 1954–79
CALVIN D. SIEBERT, University of Iowa, AND MAHMOOD A. ZAIDI, University of Minnesota
Wage-Price Behavior in Australian Manufacturing Industry
Discussants: PAUL G. REINHARDT, York University
ARNOLD KLING, Board of Governors of the Federal Reserve System

10:15 A.M. IMPACT OF THE MONETARY CONTROL ACT OF 1980: PANEL DISCUSSION (Joint Session with American Finance Association)
Presiding: ROBERT CARSWELL, University of Pennsylvania
Panelists: EDWARD C. ETTIN, Board of Governors of the Federal Reserve System
JOHN J. MINGO, Golembe Associates
RICHARD G. MARCIS, Federal Home Loan Bank Board
KENNETH R. BIEDERMAN, City Federal Savings and Loan

10:15 A.M. SOCIALIST ECONOMIC REFORM REVISITED (Joint Session with the Association for Comparative Economic Studies)
Presiding: ABRAM BERGSON, Harvard University
Papers: BELA BALASSA, Johns Hopkins University and World Bank
Reforming the Hungarian New Economic Mechanism
STEPHEN SACKS, University of Connecticut
Current Trends in Yugoslav Self-Management
THOMAS G. RAWSKI, University of Toronto
The Chinese Economy: Post Mao
Discussants: EDWARD A. HEWETT, The Brookings Institution
SVETOZAR PEJOVICH, University of Dallas
ROBERT DERNBERGER, University of Michigan

10:15 A.M. COOPERATIVE *R&D*: ISSUES AND POLICIES
Presiding: JAMES P. GANDER, University of Utah
Papers: JAMES P. GANDER, University of Utah
Theory of the Firm, Technological Change, and Cooperative Research
BRIAN PECKHAM, University of Utah
Conflict between Patent and Antitrust Law: Implications for Cooperative Research
FREDERICK BETZ, National Science Foundation
Interface of Science and Technology in the High Technology Industrial Sectors
Discussants: JOHN E. TILTON, Pennsylvania State University
JOSEPH E. FORTENBERRY, Antitrust Division, U.S. Department of Justice

10:15 A.M. NEW DIRECTIONS IN THE HISTORY OF ECONOMIC THOUGHT (Joint Session with the History of Economics Society)
Presiding: DUDLEY DILLARD, University of Maryland
Papers: LAWRENCE H. WHITE, University of California-Los Angeles
Free-Banking Thought in the British Monetary Controversies, 1820-1850
DAVID LEVY, Analytical Sciences Corporation
Choice Theory for Choosing Theorists: Smith and Kant Respond to Mandeville
GEOFFREY GILBERT, Hobart and William Smith Colleges
Senior, Scrope, and Marx on the Amelioration of Irish Poverty
Discussants: GERALD EPSTEIN, Williams College
MICHAEL WATTS, Purdue University
SALIM RASHID, University of Illinois

10:15 A.M. INVITED STUDENT PAPERS (Joint Session with Omicron Delta Epsilon)
Presiding: ALAN A. BROWN, University of Windsor
Papers: GRAHAM CLAYTON, University of Michigan and University of Windsor
Factor Distribution Effects of the Ontario Municipal Business Tax
Discussants: STEVEN BROUGHAM, State University of New York-Stony Brook
HERMAN QUIRMACH, The Rand Corporation and University of Southern California
JOHN SOUTH, Indiana University-Northwest

10:15 A.M. RESEARCH ON THE ECONOMICS OF CRIME AND ITS POLICY SIGNIFICANCE
Presiding: PETER PASSELL, *The New York Times*
Papers: CHARLES MALLER, Mathematica Policy Research
Employment-Program Impacts on Crime: An Appraisal
RICHARD MCGAHEY, Vera Institute of Justice
Labor Market Structure and Crime
KENNETH WOLPIN, Yale University
The Impacts of Punishment on Crime
Discussants: MICHAEL BLOCK, The Hoover Institution
MICHAEL BORUS, Ohio State University

0:15 A.M. THE ECONOMICS OF URBAN REVITALIZATION (Joint Session with National Economic Association)
Presiding: BERNADETTE CHACHERE, Atlanta University
Papers: WILLIAM SHEFTAL, Morehouse College
The Residential Investment Decision
DOUGLAS JOHNSON, Massachusetts Institute of Technology
The Business Location Decision
PHILLIP CLAY, Harvard University and Massachusetts Institute of Technology
Managing the Revitalization Process
Discussants: DONALD DESKINS, University of Michigan
WILHELMINA LEIGH, National Urban League

10:15 A.M. GOVERNMENT SUPPORT OF ECONOMICS RESEARCH: AN EVALUATION
Presiding: RICHARD A. MUSGRAVE, University of California-Santa Cruz
Papers: F. THOMAS JUSTER, University of Michighan
(Title to be announced)
JAMES H. BLACKMAN, National Science Foundation
(Title to be announced)
Discussants: CHARLES PLOTT, California Institute of Technology
(Others to be announced)

Editor's Note:
*Papers from sessions marked with an asterisk will be published in the *Papers and Proceedings* issue of the *Review*, May 1982.

ANNOUNCEMENTS

The ninety-fourth annual meeting of the American Economic Association will be held in Washington, D.C., December 28–30, 1981.

The Professional Placement Service will be located at the Sheraton-Washington Hotel. It will be open from 10:00 A.M. to 5:00 P.M., December 27; 9:00 A.M. to 5:00 P.M., December 28–29; and 9:00 A.M. to 12:00 noon, December 30.

Members wishing to give papers or make suggestions for the program for the AEA meeting, New York, December 28–30, 1982, are invited to write to Dr. W. A. Lewis, Department of Economics, Princeton University, Princeton, NJ 08544. To be considered for the contributed sessions, abstracts of (noneconometric) papers must be received no later than March 1, 1982.

The International Economic Association is organizing in 1981, 1982, and 1983 various roundtable conferences preliminary to a world congress on "Structural Change, Economic Interdependence, and World Development." Authors of recent contributions to aspects of this subject are invited to send abstracts to the Secretariat of the IEA (4 rue de Chevreuse, 75006 Paris, France) so that they may be forwarded to the different organizers of the roundtable conferences, and/or for the congress. A copy might also be sent to the President of the IEA, Professor Victor L. Urquidi, El Colegio de Mexico, Camino al Ajusco No. 20, Mexico 20, D. F., Apartado Postal 20-671, Mexico

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The German Marshall Fund Fellowship Program is an annual competition which awards individual research grants to scholars and professionals whose projects may contribute to a better understanding of significant contemporary problems common to industrialized societies. Projects must focus on comparative aspects of domestic and international problems, and must include the United States and at least one European country. The Program does not support work leading to a degree. Applications must be postmarked no later than November 30, 1981. For additional information and application forms, contact: The German Marshall Fund of the United States, 11 Dupont Circle, N.W., Washington, D.C. 20036.

On the occasion of the twenty-fifth anniversary of the Econometric Institute, an international symposium will be held, January 12–15, 1982. General information is available from the Symposium Secretary, Dr. B. S. van der Laan, Econometric Institute, Erasmus University, P. O. Box 1738, 3000 DR Rotterdam, The Netherland (telephone 010-525511).

The Office of Fusion Energy in the U.S. Departmen of Energy has budgeted $90,000 (fiscal year 1982) t support meritorious unsolicited proposals to perforn analysis of the economics of magnetic fusion energ research and development, deployment, and commercia operation. Contact C. R. Head, ER-532, GTN, Office o Fusion Energy, U.S. Department of Energy, Washing ton, D.C. 20545 (telephone 301+353-4954), and reques NPI ER-81-002 for full information.

The third annual Sewanee Economics Symposium i being held on October 3–5, 1981. "Perspectives on th Stagflation Economy" is the topic. Attention will b focused on the policy context of the problem (ranging from budgetary and monetary policy to measures such as *TIP*) mainly in the United States, but also abroad For further information, contact Professor Marvin E Goodstein, Department of Economics, The University of the South, Sewanee, TN, 37375.

The Division of Science Resources Studies of the National Science Foundation announces the continuation of its Program for the Analysis of Science Resources. Grants will be awarded for studies focusing on aspects of: training and employment of scientific and technical personnel; funding of scientific and technical activities; and outputs and impacts of scientific and technical activities including technological progress functions. Proposals may be submitted at any time; however, they should be received by the week of November 15, 1981, to insure consideration for funding in the 1982 fiscal year. Most awards are expected to be for one to two person-years of effort. The announcement for the *Program for the Analysis of Science Resources* (NSF 80-19) may be obtained from Division of Science Resources Studies, National Science Foundation, 1800 G Street, NW, Washington, D.C. 20550.

The Council for European Studies announces the Third International CES Conference of Europeanists to be held in Washington, D.C., April 29–May 1, 1982. The conference theme is "Periods and Cycles in Europe—Past and Present." Scholars are invited to submit suggestions for participants, panels, and papers by November 1, 1981. Panel and paper proposals should be accompanied by a short precis of proposed content and an abbreviated vita. Address: Council for European Studies, Conference 1982, 1429 International Affairs Bldg, Columbia University, New York, NY 10027.

Predissertation Fellowship Program: Applications are invited from all social sciences and related disciplines for approximately ten fellowships per year during the next two years. Graduate students, intending to pursue the doctorate, who will have completed at least two years of graduate study at an American or Canadian university by June 1982 are eligible. They must be citizens or permanent residents of the United States or Canada. The awards are $2,000 maximum; the application deadline (including reference letters) is January 15, 1982. Address: Council for European Affairs, 1429 International Affairs Bldg, Columbia University, New York, NY 10027.

Call for Papers: Montego Bay, Jamaica will be the site of the thirteenth International Atlantic Economic Conference, February 11–16, 1982. Those wishing to present papers should include a submission fee ($15.00 U.S.) for each paper plus two copies of a 500-word summary and a separate cover sheet giving location of conference; name(s), address, telephone number, institution or affiliation of author(s); number and name of the *JEL* category under which the article primarily belongs. Those wishing to be discussants or chairmen should also submit the above information to John M. Virgo, Program Chairman, Atlantic Economic Conference, Box 258, Worden, IL 62097.

Call for Papers: The Eastern Finance Association will hold its eighteenth annual meeting in Jacksonville, Florida, April 22–24, 1982. Send a two-page, single spaced abstract of your paper, indicate your interest in organizing a panel, or note your interest in serving as a chairperson/discussant. Send proposals to participate before October 31, 1981 to Philip L. Cooley, Vice President-EFA Program, College of Business Administration, University of South Carolina, Columbia, SC 29208. Information on lodging and travel can be obtained from Charles W. Young, College of Business Administration, University of North Florida, Jacksonville, FL 32216.

Call for Papers: The Southwestern Economics Association will hold its next meeting in San Antonio, Texas, March 17–20, 1982 in conjunction with the sixtieth annual meeting of the Southwestern Social Science Association. Proposals for papers or to chair or discuss can be submitted until November 15 to David E. R. Gay, President, Southwestern Economics Association, Department of Economics, BA 402, University of Arkansas, Fayetteville, AR 72701 (telephone 501+575-4002).

Call for Papers: The eleventh edition of *Socioeconomic Issues of Health* (*SIH*) will be published in December 1982. *SIH* is devoted to all aspects of the health care delivery system. Special consideration will be given to empirical and/or theoretical papers that deal with issues of public policy. Abstracts should be submitted no later than January 1, 1982, and papers no later than May 1, 1982, to Editor, *Socioeconomic Issues of Health*, Center for Health Services, Research & Development, American Medical Association, 535 North Dearborn Street, Chicago, IL 60610.

Call for Papers: The eleventh edition of *Profile of Medical Practice* (*Profile*) will be published in June 1982. *Profile* considers research on current social, economic and policy issues related to health care in the United States. Special consideration is given to empirical articles; however, theoretical articles of direct policy relevance will be considered. Abstracts should be submitted no later than October 31, 1981, and papers no later than January 1, 1982, to Editor, *Profile of Medical Practice*, Center for Health Services, Research and Development, 535 North Dearborn Street, Chicago, IL 60610.

Call for Papers: An international statistics meeting will be held at the Hebrew University, June 14–18, 1982. It is organized by the Israel Statistical Association, and cosponsored by the Israeli Academy of Sciences and Humanities, the Hebrew University, and the International Association of Survey Statisticians. There will be two main subjects: Analysis of Sample Survey Data, including theoretical foundations and methods of analysis of data from sample surveys and their application, and the design of analytical surveys; and Sequential Analysis, including optimality of sequential procedures in estimation and testing, applications of sequential procedures, and theory of stopping rules. Short abstracts of papers and requests for further information should be sent to J. Yahav or G. Nathan, Department of Statistics, Hebrew University, Jerusalem, Israel 91904.

Call for Papers: The twenty-first annual meeting of the Western Regional Science Association will be held at the Miramar Hotel in Santa Barbara, California, February 25–27, 1982. Potential topics for the program include: resource utilization, location of economic activity, regional and urban planning, environmental quality, transportation problems, locational criteria for public services and facilities, housing (financing, renewal), tourism and recreation, and energy issues. Those wishing to present a paper or serve as a discussant, contact Lay James Gibson, Executive Secretary, WRSA, Department of Geography and Regional Development, University of Arizona, Tucson, AZ 85721. The deadline for final papers is October 15, 1981.

Fellowships: The National Humanities Center will admit approximately forty Fellows for the academic year 1982–83. The Center, an institute for advanced study in fields of the humanities, is designed to foster individual research and intellectual exchange within a community of scholars. Its Fellows have the use of private studies, conference rooms, and a dining area. They are provided with library service and manuscript typing. Fellows pursue their own research and are free to participate in interdisciplinary seminars, lectures, and conferences. Fellowships are awarded on the basis of open competition; applications are welcomed from scholars in the United States and abroad. In addition to scholars from fields traditionally associated with the humanities, representatives of the natural sciences, the social sciences, and professional life may apply. The deadline for 1982–83 applications is January 10, 1982. Information and application material may be obtained from the National Humanities Center, P. O. Box 12256, Research Triangle Park, North Carolina 27709.

Fellowships: Nominations for Sloan Research Fellowships are due by September 15. Candidates must be members of the faculty at a college or university in the United States or Canada, and must be at an early stage of their research careers. For full information, write Sloan Research Fellowships, Alfred P. Sloan Foundation, 630 Fifth Avenue, New York, NY 10111.

The Social Science Research Council, through its Center for Coordination of Research on Social Indicators, has undertaken a program of planning for U.S. research on the measurement of social change in the next decade. The project is intended to anticipate new and continuing needs for research on indicators of changes occurring in society, to provide forums for discussion and evaluation of research issues, and to make it possible for statistical and research funding decisions to reflect the needs of research on social indicators. This project is briefly described in the December 1980, *Social Indicators Newsletter*, available on request from Social Science Research Council, Center for Social Indicators, 1755 Mass. Ave, NW, Washington, D.C. 20036.

The Woodrow Wilson International Center for Scholars, Washington, D.C., seeks outstanding project proposals representing diverse scholarly interests and approaches from individuals throughout the world. The Center's residential fellowships are awarded in two rather broad programs—History, Culture, and Society, and American Society and Politics—and four more focused international categories: the Kennan Institute for Advanced Russian Studies, the Latin American Program, the East Asia Program, and the International Security Studies Program. For academic participants, eligibility is limited to the postdoctoral level; for participants from other backgrounds, equivalent maturity and professional achievement are expected. Fellows devote their full time to research and writing. The length of a fellowship can vary from four months to a year. Within certain limits, the Center seeks to enable each fellow to meet his or her earned income during the preceding year. Deadline for receipt of applications is October 1, with decisions by mid-February. Appointments cannot begin before the following September. For information and application materials contact The Wilson Center, Smithsonian Institution Building, Room 321, Washington, D.C. 20560 (telephone (202)357-2841).

The Wall Street Review of Books (*WSRB*) is recruiting reviewers to write article length reviews in economics, finance, business, economic and business history, insurance, and other areas of business in general. Potential reviewers are invited to send credentials and suggested titles for review to David O. Whitten, Managing Editor *WSRB*, Department of Economics, Auburn University, Auburn, AL 36849. (*WSRB* does not pay cash for reviews.)

Economists who are strongly oriented toward the humanities, who use humanistic methods in their research, and who will be participating in meetings held outside the United States, Mexico, and Canada that are concerned with the humanistic aspects of their discipline are eligible to apply for small travel grants of the American Council of Learned Societies. Financial assistance is limited to air fare between major commercial airports and will not exceed one-half of projected economy-class fare. Social scientists and legal scholars who specialize in the history or philosophy of their disciplines are eligible if the meeting they wish to attend is so oriented. Applicants must hold a Ph.D. degree or its equivalent, and must be citizens or permanent residents of the United States. To be eligible, proposed meetings must be broadly international in sponsorship or participation, or both. The deadlines for applications to be received in the ACLS office are: meetings scheduled between July and October, March 1; for meetings scheduled between November and February, July 1; for meetings scheduled between March and June, November 1. Please request application forms by writing directly to the ACLS (Attention: Travel Grant Program), 800 Third Avenue, New York, NY 10022, setting forth the name, dates, place, and sponsorship of the meeting, as well as a brief statement describing the nature of your proposed role in the meeting.

Visiting Foreign Scholar

J. Matthias Graf Schulenburg, University of Munich (West Germany): visiting fellow, Woodrow Wilson School of Public and International Affairs, Princeton University, Sept. 1981–Aug. 1982.

Promotions

Shaun C. Bamford: assistant professor, department of economics, Rutgers College-New Brunswick, July 1, 1981.

Marion S. Beaumont: professor of economics, California State University-Long Beach, Aug. 1977.

Josef Brada: professor of economics, Arizona State University, Aug. 1981.

Paul Burgess: professor of economics, Arizona State University, Aug. 1981.

Judith M. Considine: lecturer, department of economics, Rutgers College-New Brunswick, July 1, 1980.

T. Windsor Fields: associate professor of economics, Miami University (Ohio), Sept. 1981.

Gerald Flueckiger: professor of economics, Miami University (Ohio), Sept. 1981.

Stephen Happel: associate professor of economics, Arizona State University, Aug. 1981.

William R. Hart: associate professor of economics, Miami University (Ohio), Sept. 1981.

William K. Hutchinson: associate professor of economics, Miami University (Ohio), Sept. 1981.

Tomotaka Ishimine: professor of economics, California State University-Long Beach, Aug. 1980.

Jerry Kingston: professor of economics, Arizona State University, Aug. 1981.

Barry S. Kolatch: assistant professor, department of economics, Rutgers College-New Brunswick, July 1, 1980.

Donald Schlagenhauf: associate professor of economics, Arizona State University, Aug. 1981.

Douglas R. Shaller: assistant professor, department of economics, Rutgers College-New Brunswick, July 1, 1980.

Tsunemasa Shiba: assistant professor, department of economics, Rutgers College-New Brunswick, July 1, 1980.

Andrew Stern: professor of economics, California State University-Long Beach, Aug. 1979.

Eugene N. White: assistant professor, department of economics, Rutgers College-New Brunswick, July 1, 1980.

Administrative Appointments

John M. Godfrey, research officer and senior financial economist, Federal Reserve Bank of Atlanta: vice president and economist, Barnett Banks of Florida, Inc., Apr. 13, 1981.

Victor P. Goldberg: chairman, department of economics, University of California-Davis, Jan. 1, 1981.

Albert W. Niemi: professor, director, Division of Research; and chairman, department of economics, University of Georgia, July 1981.

John J. Siegfried: chairman, department of economics and business administration, Vanderbilt University, Sept. 1980.

Richard Winkelman: acting chair, Arizona State University, July 1, 1981.

Appointments

Kathryn H. Anderson: assistant professor of economics, Vanderbilt University, Sept. 1980.

Charles M. Becker: assistant professor of economics, Vanderbilt University, Sept. 1981.

Michael David Bordo: professor of economics, University of South Carolina, Sept. 1981.

Cletus C. Coughlin, Drake University: assistant professor of economics, University of Georgia, Sept. 1981.

James Dunlevy: associate professor of economics, Miami University (Ohio), Sept. 1980.

Roger Faith, Virginia Polytechnic Institute and State University: associate professor of economics, Arizona State University, Aug. 1981.

Ira N. Gang, Cornell University: assistant professor, department of economics, Pitzer College, Sept. 1981.

Timothy Hannan, Philadelphia Federal Reserve Bank: associate professor of economics, Arizona State University, Aug. 1981.

James A. Lehman, Duke University: assistant professor, department of economics, Pitzer College, Sept. 1981.

John Lunn: assistant professor of economics, Miami University (Ohio), Sept. 1980.

Roger A. McCain, Temple University: professor of economics, Fordham University, Sept. 1, 1981.

Mark Meitzen: assistant professor, economics department, Eastern Michigan University, Sept. 1, 1981.

James Moser: instructor of economics, Miami University (Ohio), Sept. 1980.

Salih N. Neftci, Boston College: professor of economics, Fordham University, Sept. 1, 1981.

Joseph Pelzman: associate professor, department of economics, George Washington University, Sept. 1, 1980.

Andrew J. Policano, Iowa University: professor of economics, Fordham University, Sept. 1, 1981.

Steven Schwartz: assistant professor of economics, Miami University (Oxford), Sept. 1980.

Jeffrey R. Shafer: assistant vice president, research and statistics function, Federal Reserve Bank of New York, Feb. 1, 1981.

Janet Smith, University of Southern California: assistant professor of economics, Arizona State University, Aug. 1981.

Scott Smith, University of Virginia: assistant professor of economics, Arizona State University, Aug. 1981.

William J. Swenson: chief, Developing Economies Division, external financing department, Federal Reserve Bank of New York, March 16, 1981.

Kishore Tandon: assistant professor in finance, Baruch College, City University of New York, Feb. 1, 1981.

Joseph V. Terza, Clarion State College: assistant professor of economics, University of Georgia, Sept. 1981.

Bill Woodland: assistant professor, economics department, Eastern Michigan University, Sept. 1, 1981.

Leaves for Special Appointment

Paul H. Rubin, University of George: senior staff economist, Council of Economic Advisors, Washington, D.C., July 1981-July 1982.

William Schneider, Jr., Hudson Institute, New York: associate director, Office of Management and Budget, Executive Office of the President, Washington, D.C., Jan. 1981.

George H. Sweeney, Vanderbilt University: economist, Antitrust Division, U.S. Department of Justice, Dec. 1980–Dec. 1981.

Resignations

Ryan C. Amacher, Arizona State University: College of Industrial Management and Textile Science, Clemson University, July 1, 1981.

Patricia V. Linton, department of economics, Rutgers College-New Brunswick, June 30, 1981.

NOTE TO DEPARTMENTAL SECRETARIES AND EXECUTIVE OFFICERS

When sending information to the *Review* for inclusion in the Notes Section, please use the following style:

A. Please use the following categories:

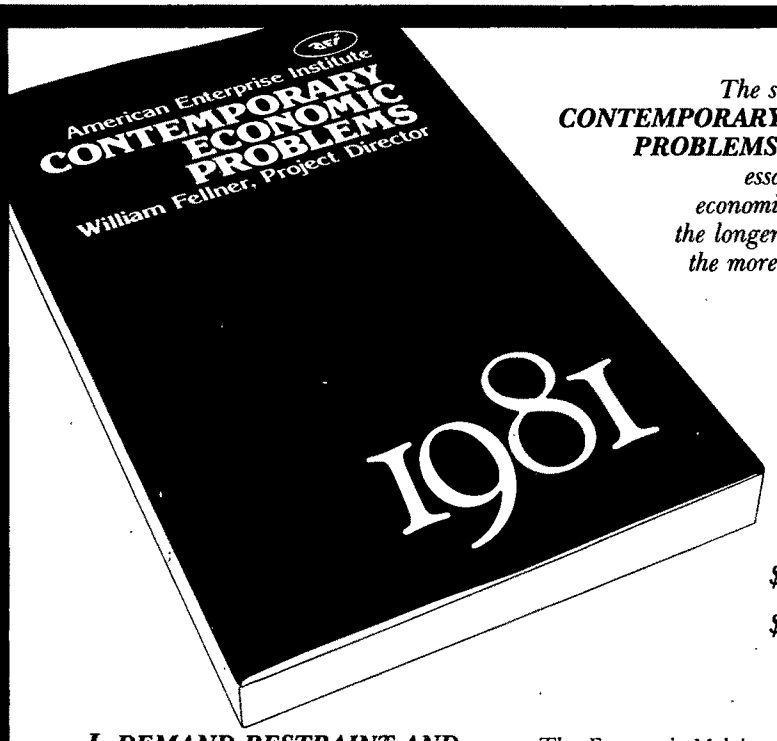
1—Deaths
2—Retirements
3—Foreign Scholars (visiting the USA or Canada)
4—Promotions
5—Administrative Appointments
6—New Appointments
7—Leaves for Special Appointments (NOT Sabbaticals)
8—Resignations
9—Miscellaneous

B. Please give the name of the individual (SMITH, Jane W.), her present place of employment or enrollment: her new title (if any), new institution and the date at which the change will occur.

C. Type each item on a separate 3×5 card and please do not send public relations releases.

D. The closing dates for each issue are as follows: *March*, October 15; *June*, January 15; *September*, April 15; *December*, July 15.

All items and information should be sent to the Assistant Editor, *American Economic Review*, Editorial Office, University of California, Los Angeles, CA 90024.



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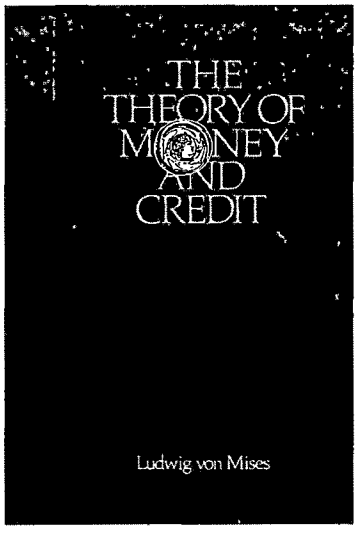

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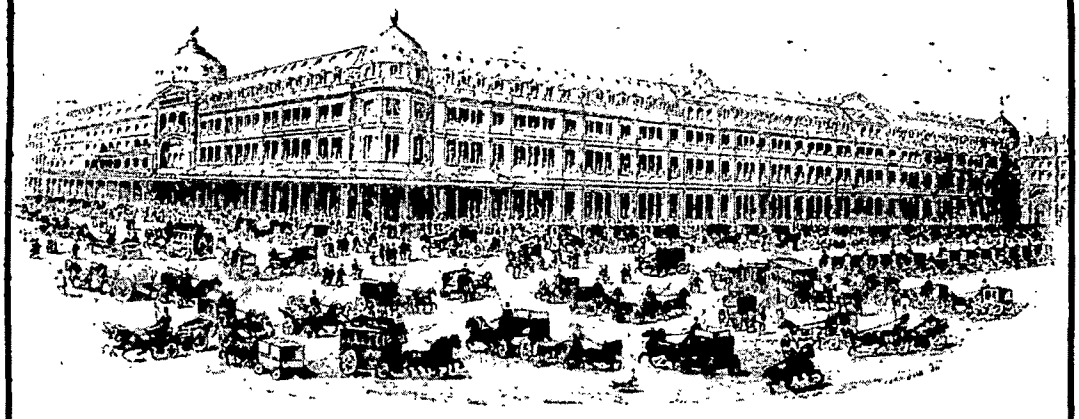

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Identification and Estimation of Money Demand

By THOMAS F. COOLEY AND STEPHEN F. LEROY*

In most natural sciences (physics, chemstry, biology) theories are validated by conrolled experiment. However, in other natual sciences (astronomy, meteorology), and in nost social sciences, including economics, he data are characteristically generated not ›y experiment but by measurement of un›ontrolled systems. In economics, theories ake the form of restrictions on the models ıssumed to generate the data, and statistical nethods replace experimental controls in testing these restrictions. And here is the difficulty: in economics, particularly macroeconomics, the theory used to derive tests ordinarily does not generate a complete specification of which variables are to be held constant when statistical tests are performed on the relation between the dependent variable and the independent variables of primary interest. Accordingly, in such cases there will be a set of often very different candidate regression-based tests, each of which has equal status with the others since each is based on a different projection of the same underlying multivariate model. Except in the unlikely event that the explanatory variables are mutually orthogonal, the conditional regression coefficients, which generally form the basis for the test statistic, will depend on the conditioning set. We conclude from this that, if a theory which does not generate a complete specification of the regression test is nonetheless to have testable implications, these implications must be robust over the permissible alternative specifications. If the restrictions indicated by the theory are satisfied in some projections, but not in others that have an equal claim to represent implications of the theory, one cannot conclude that the theory has been confirmed.

The fact that the observable implications of valid theories must obtain over a broad (but usually incompletely specified) set of regressions rather than for a single regression introduces a large and unavoidable element of imprecision into hypothesis testing in macroeconomics. Generally it appears to be appropriate to weaken the statistical criterion for rejecting theories. Consider, for example, the theory of money demand, which will engage our attention in this paper. The Tobin-Baumol square root formula implies that the elasticity of money demand with respect to the interest rate is exactly one-half. But which interest rate? Should wealth be held constant? Inflation? In view of such uncertainties it would be inappropriate to insist in a literal-minded fashion on rejecting the Tobin-Baumol model if in some regression the measured interest elasticity differed from one-half by more than two standard deviations, and only then. Obviously a more flexible approach is called for. The practice has been to conclude that the statistical evidence is consistent with the Tobin-Baumol model as long as the interest rate coefficient is negative. If it is negative and significant, or negative and insignificantly different from minus one-half, that would provide somewhat stronger confirmation. But a positive coefficient, particularly a significantly positive coefficient, would be viewed as raising questions about the validity of the theory. In macroeconomics generally, as in the money demand application, the typical response to specification uncertainty has been to regard a theory as supported if the signs of the estimated coefficients agree with those expected from theory, and as disconfirmed otherwise. There is no theoretical justification for this procedure, but it seems to be a reasonable course to follow.

The point that economic theory ordinarily generates incompletely specified statistical

*University of California, Santa Barbara. We have received helpful comments from Andrew Abel, Robert Clower, Michael Darby, Robert Engle, Stephen Goldfeld, David Laidler, Edward Leamer, Robert Lucas, Frederic Mishkin, and Edward Prescott. Thomas Hall provided able research assistance.

tests, and that therefore conclusions based on empirical tests must be robust to at least some respecifications, is obvious when stated directly and in abstract form. But consider its implications when combined with some equally well-known facts about the sociology of scientific research. In any science the rewards go disproportionately to the researcher who proposes a new theory which is empirically confirmed, and not to the analyst who proposes, tests, and rejects another equally appealing theory. This bias is an inevitable consequence of the fact that plausible but wrong theories are easier to come upon than new, correct and important theories. But the bias has the consequence that incentives are created for the scientist to become an advocate for his theory, presenting all the evidence he can find in its favor and leaving to others the task of mobilizing contrary evidence.[1]

To some extent the search of the scientific community for adequate explanation may be likened to that of the legal community for justice: in a court case the lawyers on each side are understood to be engaged in special pleading, subject only to minimal requirements prohibiting perjury, and so forth. For the most part in the natural sciences the fact that scientists act as advocates does not seriously impede communication since there is little latitude for selectivity in reporting experimental evidence, short of outright falsification. But in economics the advocacy nature of scientific work creates special prob lems, in part because macroeconomic theor does not generate completely specified em pirical tests corresponding to the controlle experiments of the natural sciences. Actin as an advocate for his theory, the economis conducting an empirical study is motivate to examine all or a large subset of the man possible regressions constituting tests of hi theory and to report only those results mos favorable to the theory. Often significanc tests and fit statistics are conducted an interpreted as if the reported regression con stituted the one statistical test unambigu ously implied by theory, even though bot researcher and reader are aware that th conventional tests are invalid if the reporte regression is in fact the outcome of a specifi cation search. The reader, of course, knowin that a specification search underlies the re ported tests, discounts heavily or completel the researcher's claims for validation of a theory for which he is obviously acting as ar advocate. At best, the reader holds ir abeyance his evaluation of the researcher's claims until he can conduct his own test fo robustness by varying the regression specifi cation over what seem to him to be equall acceptable tests of the theory and determin ing the degree to which the outcome of th test conducted by the researcher is affecte by such respecification. Particularly in mac roeconomics, therefore, we often have wha is very nearly a zero-communication infor mation equilibrium. The researcher has th motive and opportunity to represent his re sults selectively, and the reader, knowing this, imputes a low or zero signal-to-noise ratio to the reported results.

We do not suggest that the advocacy system is the culprit here. Legal scholars do no believe that justice would be better served i lawyers sacrificed their clients' interests in favor of their own perceptions of justice, just as most economists do not believe that corporate executives would in fact serve the public welfare by subordinating to their conception of it their obligations to shareholders. Similarly, we see little point in urging that researchers in economics forswear their roles as advocates. Rather, we believe that what is needed is a form of communica-

[1]As is well known, economics journals strongly reinforce the advocacy element in communication among researchers by publishing negative results rarely, and fully reported specification searches almost never. The few exceptions to this rule are generally papers authored by scholars of established reputation (in money demand theory, see for example the papers of Stephen Goldfeld, 1973; 1976, and David Laidler, 1980). For these an exception is made, presumably because of the widespread respect for their judgment and ability to conduct a specification search that will be of general interest. One may or may not agree with the details of the specification search reported in such papers as Goldfeld (1973) (see the discussion below); however, the point here is that such papers provide a more complete report of specification searching than is commonly the case, and the reader is therefore in a better position to determine for himself whether he shares the author's conclusions. But for the majority of papers reported in the journals, no such independent judgment is possible.

ion that is less amenable to selective reporting, so that economists, still acting as advocates, can conduct and report tests in a way hat will not be so highly discounted by eaders.

Gary Chamberlain and Edward Leamer nd Leamer's book have developed analytical results consistent with such a reporting style, and Leamer and Herman Leonard have discussed how they can be used to achieve more effective communication. Leamer's idea is to represent specification uncertainty by dividing the explanatory variables in a regression into two classes: the "focus variable" and the "doubtful variables." The researcher's purpose is assumed to be to estimate or perform tests on the coefficient of the focus variable. However, the researcher is assumed to be a priori uncertain about whether the effect of other variables should or should not be controlled, and he wishes to ascertain the sensitivity of the estimated focus coefficient to the inclusion or noninclusion of such doubtful variables in the regression. Accordingly, Leamer proposed reporting the extreme values of the focus coefficient over a suitably defined region of the parameter space, where the parameter space includes the coefficients of both focus and doubtful variables. Such a reporting procedure, which would replace the prevailing practice of selective reporting of the results of a specification search, would allow the researcher to demonstrate the robustness of his conclusions with respect to a clearly defined set of respecifications. Accordingly, it offers some prospect of improving the informativeness of communication among researchers in macroeconomics.

Suppose that we conduct an empirical investigation in the manner recommended by Leamer, and assume that it is concluded that the parameter restrictions implied by the theory do not appear to be satisfied in the majority of the conducted regression tests. In that case one of two conclusions must follow. The first, of course, is that the theory is incorrect. The second possible explanation, which will occupy us in this paper, is that least squares projections do not provide a suitable analogue to the controlled experiments of the natural sciences. A number of econometric problems may lead to such failure of experimental design, but that which will interest us primarily is simultaneity. If simultaneous equations problems are present, the estimated coefficients of least squares projections do not correspond to the structural parameters which are restricted by the theory. Consequently, the empirical acceptance or rejection of these restrictions has no implication for the theory. In any particular case, the judgment as to whether empirical rejection of the theory is due to the incorrectness of the theory or to the existence of simultaneous equations (or other statistical) problems will depend on the strength of the researcher's prior belief in the correctness of the theory relative to that of his prior belief in the validity of the least squares specification: if the researcher is certain that the least squares specification is acceptable, he will conclude from his empirical results that the theory being tested is false, while if he is certain that the theory is correct he will conclude that simultaneity problems are present and serious.

In this paper we consider the application of these ideas to the estimation of models of money demand. We will take it as an implication of theory that the demand for money depends on an interest rate, representing the opportunity cost of holding real balances, and a measure of transactions. Further, we will assume without discussion that theory implies a negative coefficient for the interest rate no matter what measure of transactions is used, and no matter what other variables are included in the regression. Thus we obtain the robustness required in view of the fact that theory does not specify precisely which variables do and do not enter the money demand regression. We wish to test this restriction empirically, and to obtain an estimate of the interest elasticity of money demand.

It is noted in Section I that the majority of empirical studies of money demand have in fact reported success in estimating a significant negative coefficient for the interest rate. But we strongly suspect that many of these studies are based on selective reporting of the results of a specification search, leading

us to discount the reports of successful testing and implementation of the theory pending some demonstration of robustness. In Section II we review Leamer's algorithm, preparatory to using it to provide the required appraisal of the robustness of the estimated interest rate coefficient to alternative specifications. Leamer's procedure is implemented in Section III. We take the Treasury bill rate and the savings and loan passbook rate as the focus variables, and include as doubtful variables a variety of other variables frequently appearing in estimated money demand models in the reported literature. It is concluded that the estimated interest elasticity is extremely sensitive to the inclusion or noninclusion of the doubtful variables, is not clearly negative, and is in any case much closer to zero than is indicated in much of the reported literature. It follows that the results reported in the literature are not in fact robust, reflecting instead highly selective reporting of a specification search that converges toward regions of the parameter space that contain "significant" negative estimated interest elasticities. Our results suggest that researchers who report successful empirical testing of the restrictions implied by theory do so primarily by building in their conclusions, and that in fact the data do not provide confirmation for the theory.

As indicated above, our failure to confirm the theory motivates a reexamination both of the economic theory being tested and of the econometric assumptions underlying the test itself. We follow only the second of these lines in this paper.[2] In Section IV the treatment in the existing literature of simultaneity problems in estimating the demand for money is reviewed. It is found that such discussions, which are extremely perfunctory and superficial, amount to dismissing the problem without serious analysis. We view this as a consequence of the fact that thoughtful discussion of simultaneity problems has no role to play in the process of persuasion, particularly if the conclusion is that suc problems are not minor. Accordingly, to th extent that researchers act as advocates for particular conclusion based on least square estimation, they have strong motivation t dismiss simultaneity problems as unim portant or to omit discussion of such prob lems altogether. Further, investigators ca always suppress estimated regressions whic give evidence of simultaneity problems—principally wrong signs—in their publishe reports, thereby avoiding the need to con front the issue. Finding that the discussion o simultaneity problems in the establishe literature is inadequate, we are led in Sectio V to inquire whether such problems can b resolved by any method not discussed in th literature. After considering and rejectin several plausible possibilities, we conclud that we are unable to devise a statistica procedure that will identify a demand rela tion.

I. The Demand for Money

The consensus account of the theory of th demand for money has changed little in th last forty years. In David Laidler's words "The picture that emerges from the preced ing brief [summary of the literature] is one o steady if unspectacular progress, of a gradua refinement of our understanding of the prop erties of the demand-for-money function, an of a considerable broadening of the empiri cal basis of that understanding" (1980, p 223). In contemporary formulations, just a in Keynes's *General Theory*, the demand fo real money is assumed to depend negativel on a short-term interest rate, representing a proxy for the opportunity cost of holdin money, and positively (and sometimes pro portionally) on a transactions measure suc as real *GNP*. The absence of fundamenta development in the theory of money demand is at least partly due to the fact that empirical studies have for the most part reported exceptional success in testing and otherwise implementing the received theory, implying no need for reexamination of the model. At least until the recent "missing money" episode, most studies have concluded that the money demand equation is stable, that the

[2]In this connection, it is worth noting that Robert Clower and Peter Howitt have argued that the comparative statics properties of the Tobin-Baumol model do not carry over to more general settings.

estimated coefficient of correlation is very high, that the estimated regression coefficients have the indicated signs and approximately the magnitudes expected from theory, and that sampling error in coefficient estimation is acceptably small. As Laidler put it, "... the frequency with which a positive real income (or wealth) elasticity of demand for money, a negative opportunity cost elasticity, and a unit price level elasticity of demand for money have been found to be well determined is quite remarkable" (1980, p. 221). Elsewhere Laidler observed that "There is an overwhelming body of evidence in favor of the proposition that the demand for money is negatively related to the rate of interest. Of all the issues in monetary economics, this is the one that appears to have been settled most decisively" (1977, p. 130). Given the consonance of the theoretical and empirical evidence on the fundamentals of money demand, most empirical investigators have felt justified in proceeding to explore elements of the regression specification which are of secondary importance. Bearing in mind the development presented in the introduction, however, we are unwilling to take entirely at face value the striking agreement reported in the literature between theory and evidence, particularly in view of the high degree of consensus on the underlying theory. With regard to the coefficient of the interest rate, is one to conclude that the evidence in fact strongly confirms the prediction from theory that it is negative? Or is it a fact that researchers have acted as advocates for the consensus theory by conducting specification searches and reporting only the evidence consistent with their prior belief in the correctness of the theory? As indicated in the introduction, our view is that the second case is closer to the truth than the first.

A convincing argument for our view cannot be based on the existing literature since our evidence must consist primarily of what is excluded from published articles rather than what is included. However, some prima facie evidence is available from the literature. If, as we argue, the conclusions reported in empirical studies of the demand for money reflect prior beliefs more than sample evidence, then differences among authors in conclusions should be traceable to identifiable differences in priors. Of course, the existence of a generally accepted consensus on the theory of money demand means that such an association is difficult to document since there exist so few differences in priors. Nonetheless, such differences in conclusions as do exist turn out to bear a pronounced correlation with differences in priors.

For Keynesians, a negative estimated interest elasticity is an absolute necessity, since otherwise the comparative statics properties of *IS-LM* type models may be reversed.[3] Monetarists, on the other hand, do not regard bond interest rates as the only, or even the most important, variable linking monetary changes with expenditures. Consequently, the issue of the interest rate elasticity is not of primary importance to monetarists. Compare, for example, Milton Friedman: "In my opinion no 'fundamental issues' in either monetary theory or monetary policy hinge on whether the estimated elasticity can for most purposes be approximated by zero or is better approximated by $-.1$ or $-.5$ or -2.0, provided it is seldom capable of being approximated by $-\infty$" (1969a, p. 155). Also, monetarist doctrine stresses the dependence of nominal interest rates on expected inflation. Consequently, monetarists could rationalize a positive association between changes in the money stock and changes in interest rates as reflecting the effect of monetary changes on expected inflation. It follows that monetarists will be much more willing than Keynesians to maintain an agnostic attitude, letting the data tell their own story, or alternatively to conclude that aggregate data do not give much information about the interest rate elasticity.

What do we find when we look at the evidence? The majority of studies of money demand were performed by economists who accept the Keynesian orthodoxy, and in these studies it is invariably found that, as expected, the coefficient of the interest rate is indeed negative and significant. To our

[3]For example, if the *LM* curve is negatively sloped and steeper than the *IS* curve, an increase in government spending will decrease rather than increase *GNP*.

knowledge the authors of only three of the major studies of money demand reported that they were unable to isolate a significant interest rate effect. These, significantly, are Friedman (1969b; first published 1959), Laidler and Michael Parkin, and Sam Peltzman, all monetarists.[4] It is true that both Friedman and Laidler subsequently succeeded in finding the usual negative coefficient (Friedman, 1969a, first published 1966; Laidler, 1977), but this only confirms our point that the monetarist view of the transmission mechanism implies that monetarists are likely to be much more willing than Keynesians to reverse their field on the question of the interest rate elasticity if the evidence appears to require it.

Rational expectations macroeconomic models provide another case in point. In these models, money affects aggregate real activity because market participants are by assumption unable to distinguish between nominal and real shocks. Interest rates, therefore, are not directly involved in the linkage between monetary shocks and changes in real activity (however, it could be argued that, in such rational expectations models as that of Robert Lucas, interest rates are implicitly involved). Consequently, researchers associated with the rational expectations tradition, like monetarists but unlike Keynesians, would not be impelled to find a negative relation between monetary changes and interest rate changes. And, indeed, Frederic Mishkin reported that "many different empirical tests [which he conducted]... uniformly *do not support* the proposition that increases in the money stock are correlated with declines in short rates" (emphasis in text). It is seen, then, that economists who subscribe to the view that the interest elasticity of money demand is negative and significant are likely to be those who think about macroeconomics in terms of models of the *IS-LM* type, while economists who do not see in the data a clear structural relation between money and interest rates tend also not to rely on such a relationship in their thinking about business fluctuations. Unless this association is to be viewed as coincidence, it appears to follow that prior beliefs play a more important role in generating posterior conclusions than is commonly acknowledged.

The most convincing evidence of the role of specification uncertainty and specification search in facilitating the combination of prior with sample information is found not by comparing the results of researchers with different priors, but by examining the informal discussion of provisional results by a given researcher, particularly in papers in which the specification search is fully reported. Generally in the money demand literature the practice is to conduct hundreds of regressions in batches of several dozen regressions each.[5] At each stage the regressions with wrong signs are discarded, and those most consistent with the researcher's preferences are interpreted and used as the basis for the next series of regressions. Much reliance is placed on estimated fit statistics in selecting the most promising regressions, although the discussion here is generally circumspect since it is well known that these statistics have no clear interpretation when the statistics themselves provide the principal guide for the specification search. Throughout the researcher relies heavily on his prior information as to what constitute "reasonable" and "plausible" specifications, which views the reader is presumed to share. Thus, the existence of considerable specification uncertainty, as in the demand for money, in practice has the effect of increasing the precision and detail of reported conclusions since it gives the researcher wide latitude for a specification search, which in turn facilitates the imposition of highly detailed prior information. Obviously the appropriate consequence of specification uncertainty would be just the opposite: to decrease the scope of the in-

[4] Friedman (1969a, p. 142, fn. 1) subsequently pointed out that in (1969b) he had concluded only that he was unable "to find any close connection between changes in velocity and any of a number of interest rates," not that a zero value could definitely be assigned to the interest elasticity.

[5] A coauthor of one of the major studies of money demand estimates that he ran more than 500 regressions in preparing his article.

ferences which can with confidence be drawn from the data.

Stephen Goldfeld's 1973 paper provides an excellent example of the infusion of extensive prior information into money demand estimation via a guided specification search. It is worth emphasizing that we single out Goldfeld's paper only because he reported the specification search more extensively than is usual; in much of the literature the same type of specification search is conducted, but only the end product is reported. Also, Goldfeld's paper is the most frequently cited of the recent empirical studies of money demand and appears to have established the precedent, followed in much of the subsequent literature, of reporting scores of regressions (in Goldfeld's case, over 70) rather than a dozen or so as formerly. We present two examples of what we believe to be Goldfeld's propensity to overinterpret the data and to use specification uncertainty as a means to impose highly articulated prior information on the data. At one point (pp. 598–607) Goldfeld wished to ascertain whether a Koyck lag with separate provision for autocorrelation (via the Cochrane-Orcutt technique) adequately represents the dynamic effect of lagged explanatory variables on money demand. To make this determination he reestimated the demand for money (characteristically, the experiment was repeated for currency and demand deposits separately) by using the Almon technique in place of the Koyck transformation. As with the Koyck specification, the Cochrane-Orcutt procedure was used to correct for serial correlation of the errors. Inasmuch as both regressions yielded a coefficient of correlation of 0.995, and since the estimated lag structures were only slightly different (they will, of course, be exactly identical with probability zero), it would seem that there is nothing to choose between the two specifications. Goldfeld's interpretation was different:

> The Almon responses to income changes are uniformly slower than the Koyck responses. For interest rates, the Almon response is slower for several quarters but then overtakes the Koyck response. Evidently, constraining all the responses to the same shape in the Koyck version produces an inappropriate average response which masks individual differences.... In summary, a modest amount of evidence suggests that the Koyck formulation of equation (4) is a bit too restrictive. [p. 607]

Although this conclusion is carefully modulated, and is then qualified by a call for additional research on the subject, it still appears to us to constitute drastic overinterpretation of regression results. For another example, consider Goldfeld's discussion of the long-run income elasticity of money demand (pp. 583–89). The estimated income elasticity is 0.68; the standard error of estimate was 0.00432 and the root mean-squared error based on a dynamic within-sample simulation was 0.0093. With the elasticity constrained to unity, the corresponding figures were 0.00457 and 0.0112. Based on these differences (and, it is true, also on a more pronounced deterioration in out-of-sample performance under the constrained version), Goldfeld concluded that "the results seem to suggest that the relevant income elasticity... is significantly less than unity" (p. 589). We believe that given the extent of specification uncertainty in the demand for money it is inappropriate to discriminate between alternative equations on the basis of such small differences in the quality of fit.

It is obvious that when an intensive specification search is employed to isolate a money demand equation which fits the sample period (and possibly also tracks the data for a few quarters beyond the sample period), a marked deterioration in performance should not be surprising when the equation is applied to data other than those used to fit the equation and conduct the specification search. That this has been the case with the equations which Goldfeld (and everyone else) estimated in the early 1970's is well known. In 1974–76 empirical money demand equations of the received variety overpredicted the money stock by a large margin. That the misses should be statistically significant according to the standard error of estimate of the preferred equation is hardly surprising in view of the fact that the *SEE* of the

preferred equation is strongly biased toward zero by the specification search. In our view an appropriate lesson to be learned from the "missing money" episode would have been that it is pointless to conduct a specification search in the manner of Goldfeld and to continue to ignore issues of identification and simultaneity. However, Goldfeld and others instead took at face value the evidence that a statistically significant shift in the money demand equation had taken place, and were therefore led to conduct yet another search for an equation that would fit the more recent data and otherwise display satisfactory characteristics (see Goldfeld, 1976, and also Jared Enzler, Lewis Johnson, and John Paulus).[6]

Instances of overinterpretation of regression results similar to those of Goldfeld could be multiplied indefinitely from virtually any of the recent empirical analyses of money demand, but there seems little point in doing so here. Evidently the problem is that the presence of specification uncertainty has induced analysts of money demand to make extensive but completely informal use of prior information. The unsystematic nature of this combining of prior and sample information makes it virtually impossible for the reader to specify what prior beliefs he has to agree to in order to assent to the conclusions of the empirical exercise. Further, it is difficult for the analyst with priors which differ from those of the author of an article to extract useful information from the reported results. Obviously what is required is a more formal and explicit means of representing prior information, or the lack of it, about model specification. Leamer's analytical procedure and reporting style are one way of fulfilling this requirement.

[6]We are unable to supply an analysis of the missing money episode because, as indicated in the introduction, we do not know how to estimate structural money demand equations consistently. However, our perspective suggests two observations. First, as indicated in the text, it is not clear that a statistically significant shift in fact occurred. Second, even if such a shift did occur it is not evident that it was demand that shifted rather than supply, or both demand and supply (the arguments of Goldfeld, 1976, and Enzler, Johnson, and Paulus that the shift was one in demand require the maintained assumption that a structural demand equation for the earlier period had been satisfactorily estimated).

In our view it may be more than coincidental that monetarist views became more influential than formerly in the Federal Reserve System around the time of the missing money episode, and it is certainly the case that among the public, monetarist interpretations of Federal Reserve policy became more widespread during those years. If a change in the Federal Reserve's response function was believed by the public to have occurred, a rational expectations argument establishes the presumption of a consequent shift in demand. Apart from the rational expectations argument, however, even if no shift in structural demand actually occurred it is still likely that if a structural supply shift occurred it might be imputed to demand, given the correctness of our contention that estimated money demand equations are probably contaminated by supply equations. We have no way to ascertain the validity of such conjectures, however.

II. Extreme Value Analysis

Consider the regression

$$y_t = x_t\beta + \sum_{i=1}^{k} z_{it}\gamma_i + u_t \tag{1}$$

and suppose that our primary interest is in estimating β, the coefficient of the "focus variable" x_t. Specification uncertainty is reflected by the inclusion of the k "doubtful variables" z_{it}. The researcher is not certain that these should be included as conditioning variables, but is unwilling to exclude them a priori. If the researcher is also uncertain that linearity is the appropriate functional form, the z_{it} may be specified to include higher-order or interaction terms. When there are k uncertain variables, 2^k regressions are defined by the inclusion or noninclusion of some or all of the doubtful variables. If k is at all large, only a small subset of these can feasibly be examined by the researcher, and the regressions reported to the public are generally a still smaller subset. But the 2^k regressions defined by on-off combinations of the doubtful variables (i.e., regressions in which each doubtful variable either receives equal billing with the focus variable or is excluded altogether) obviously constitute a subset of a broader class consisting of those regressions which incorporate general linear restrictions among the doubtful variables. Aside from convenience, there is no reason whatever why

ıttention should be limited to the less gen-
:ral class of regressions.

A formal Bayesian approach in which be-
iefs about the doubtful variables were repre-
ented by a well-defined prior distribution
vith the prior location and covariance ma-
:rix specified would lead to a well-defined
osterior distribution for β. The problem is
hat while it is usually easy to specify the
rior location, it is generally difficult to
specify the covariance matrix. The approach
ised in this paper is based on a result by
Chamberlain and Leamer, further elaborated
n Leamer, which obviates the need for
specification of the prior covariance matrix.
The theorem is that specification of the prior
ocation and the sample covariance matrix is
ufficient to constrain the posterior means to
ie within a particular ellipsoid, the "locus of
onstrained estimates."[7] To understand in-
uitively the meaning of the locus of con-
strained estimates, consider the special case
of equation (1) in which there are two doubt-
ul variables:

$$y_t = x_t\beta + z_{1t}\gamma_1 + z_{2t}\gamma_2 + u_t. \tag{2}$$

We can define a composite variable,

$$w_t(\theta) = z_{1t} + \theta z_{2t},$$

and rewrite equation (2) as

$$y_t = x_t\beta + w_t(\theta)\gamma + u_t.$$

For suitably defined θ this regression coincides with any of the four regressions defined by including both doubtful variables, deleting one or the other, or deleting both. These four points are indicated by $(\hat{\gamma}_1, \hat{\gamma}_2)$, $(0, \hat{\gamma}_2)$, $(\hat{\gamma}_1, 0)$, and the origin in Figure 1. But, as already noted, there is no reason to restrict attention to these four regressions. For each value of θ there is a different regression and corresponding estimate of the focus coefficient $\hat{\beta}(\theta)$. The set of all possible values of (γ_1, γ_2) generated by varying θ over the real line will define the ellipse of constrained estimates, indicated by the dashed line in Figure 1. The significance of this ellipse is that it contains all possible posterior means for the distribution of (γ_1, γ_2) that result from the integration of a prior distribution centered at the origin with the sample (i.e., if the covariance matrix of the prior distribution is varied over all possible 2×2 positive definite or semidefinite matrices, the resulting set of posterior means for (γ_1, γ_2) is just the ellipse of constrained estimates and the points within it).

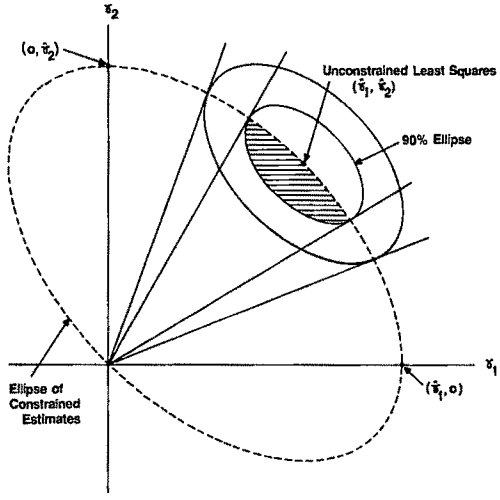

FIGURE 1. ELLIPSOIDS OF CONSTRAINED LEAST SQUARES POINTS

One measure of specification uncertainty is obtained by calculating the extreme values of $\hat{\beta}(\theta)$ on the locus of constrained estimates. If the difference between the extreme values is large relative to the sampling uncertainty, the implication is that uncertainty in model specification is a major contributor (relative to sampling variance) to the overall uncertainty about the value of the focus coefficient. The appeal of this estimation procedure lies in the fact that, although it is Bayesian in spirit, it does not require the analyst to define the relative strength of his prior belief that the coefficient of each of the doubtful variables equals zero; rather, the idea is to evaluate specification uncertainty by searching for the extreme values of the

[7]Specifically, in the regression model $y = x\beta + u$ with sample estimate and prior location b and b_0, respectively, and sample precision matrix H, the mean of the posterior distribution is constrained to lie in the ellipsoid $(b-b_0)'H(b-b_0)/4$.

estimated focus coefficient that can occur over all possible prior covariance matrices.

The major shortcoming of the measure of uncertainty just described is that the extreme values on the locus of constrained estimates may occur at locations in the parameter space which are extremely unlikely in view of the data. To meet this objection, Leamer proposed a related measure of specification uncertainty, one that we will employ. Consider the set of points $(\hat{\gamma}_1, \hat{\gamma}_2)$ defined by the intersection of the points in the interior of the locus of constrained estimates and, say, the 90 percent likelihood ellipse. This set is indicated by the shaded region in Figure 1. The interpretation is that parameter pairs in the region just defined represent all the possible parameter pairs that could be generated as posterior estimates from some prior distribution centered at the origin, subject to the further constraint that only points in the 90 percent likelihood ellipsoid be considered. The 90 percent ellipsoid is generated in the usual way under the assumption that all doubtful variables enter the regression. The measure of specification uncertainty is simply the difference between the extreme values of the estimated focus coefficient over this region. There is, of course, no reason to look at the 90 percent ellipsoid rather than any other; consequently, we will display the extreme values of the focus coefficient over a sequence of likelihood ellipsoids, the idea being to evaluate how specification uncertainty varies for different possible relative weights on the sampling and prior distributions.

III. Empirical Implementation[8]

The equation we consider first relates the demand for real money (M1) to a measure of transactions and to two interest rate variables, the savings and loan passbook rate (RSL) and the ninety-day Treasury bill rate (RTB). Our prior belief (as in, for example, Franco Modigliani, Robert Rasche, and J. Philip Cooper) is that the long-run income elasticity of the demand for money is unity. We estimate the equation in log-linear form both because in doing so we follow precedent and because the resulting coefficients have an immediate interpretation in terms of elasticities. The data are quarterly and the observation interval is 1952.2 to 1978.4. The equation corresponding to our prior beliefs in which all the doubtful variables are excluded, would then be estimated by regressing the *log* of the real money stock (M1) less the *log* of real *GNP* on the *log* of the ninety-day Treasury bill rate and (or) the savings and loan passbook rate. There exists a variety of additional variables which may influence the demand for money in addition to, or as alternatives for, those variables already specified. Under the usual estimation procedure as described in Section I, various subsets of these variables would be included in the specification search; here, on the other hand, we label them "doubtful variables" and treat them in the manner outlined in the preceding section. We do not contend that our list of doubtful variables exhausts the set of variables entered in money demand equations in all the studies extant, although we have tried to include those which have received major attention in the most widely cited articles. Expansion of the set of doubtful variables would only increase the estimated extreme values for the interest rate coefficient and therefore strengthen our conclusion. Our set of doubtful variables is listed and briefly described in Table 1. All were entered in *log* form.

Least squares applied to the basic equation with all doubtful variables (except the lagged terms) included yields the following estimates (standard errors in parentheses)

$$(3)\quad ln(M_t/P_t) - ln(GNP_t/P_t) = -\underset{(.813)}{1.818} + \underset{(.011)}{0.010} \cdot ln\, RTB_t - \underset{(.069)}{0.175}\, ln\, RSL_t - \underset{(.167)}{0.036}\, ln(\dot{P}_t/P_t) - \underset{(.081)}{0.628}\, ln(GNP_t/P_t) - \underset{(.055)}{0.009}\, ln\, VCC_t + \underset{(.096)}{0.107}\, ln W_t.$$

$$R^2 = .985;\ SEE = .028.$$

[8]The program used in the empirical work reported in this section was SEARCH, developed by Leamer and Leonard.

TABLE 1—DOUBTFUL VARIABLES

Real GNP. Real *GNP* (i.e., nominal *GNP* divided by the *GNP* deflator) was entered as a doubtful variable to allow for the possibility that the income elasticity of money demand is greater than or less than unity.

2. The current *inflation rate* ($\dot{P}/P$) (the rate of change of the *GNP* deflator) was entered as a doubtful variable; this variable could be excluded on prior grounds if we were certain that financial assets are the only relevant alternatives to money, since in that case the inflation rate would be relevant only insofar as it affects nominal interest rates, which are already included as explanatory variables. However, we wish also to allow for the possibility that commodity inventories are relevant alternatives to fixed yield financial assets, in which case there may be a role for the inflation rate independent of nominal interest rates.
3. The real value of *credit card transactions* (*VCC*) was included to capture the possible negative effect of increased credit card use on money demand.
4. *Real Wealth* (*W*) was included on the grounds that some discussions of the demand for money (see, for example, Friedman, 1969b) emphasize wealth as a major determinant of money demand. Our measure is that used in the MIT-Penn-SSRC econometric model.
5. As indicated in the text, *lagged values* of the above variables are included in one specification together with lagged values of the focus variables to allow for lagged adjustment to the equilibrium.

Thus, if all doubtful variables are included the estimated interest elasticity (the sum of the coefficients of *RTB* and *RSL*) is -0.165 and the interval -0.013 to -0.317 (i.e., -0.165 ± 0.152, the sampling uncertainty of the sum of the coefficients of *RTB* and *RSL*) would include the true value with 95 percent probability. These particular estimates would not be of much interest to most investigators since it is obvious that even a rudimentary specification search would produce an equation deemed more worthy of reporting (for example, the coefficients of most of the explanatory variables in (3) are not significantly different from zero). Equation (3) is, of course, not relevant to our analysis since it makes no use of our prior belief that the doubtful variables may be excludable from the regression.

In Table 2, Specification 1 presents the extreme bounds on the sum of the coefficients of the focus variables *RTB* and *RSL* for various values of the data likelihood. The difference between the extreme bounds is a measure of the uncertainty in the interest elasticity of the demand for money that results from uncertainty about the specification. Clearly the specification uncertainty is very large compared to the sampling uncertainty (0.152), and the bounds include positive values for most values of the data confidence.

One of the problems that confronts all empirical studies of money demand is the existence of collinearity among interest rates. In several studies it is concluded that collinearity among interest rates is sufficiently great that little explanatory power is lost if only one interest rate is entered in the regression. It is therefore useful to estimate bounds on the interest elasticity when only one interest rate is included as a focus variable. Accordingly, in Specification 2 we deleted *RSL* from the model. The list of doubtful variables is assumed unchanged. Interestingly, when *RSL* is excluded the extreme bounds of the coefficient of *RTB* become quite narrow except at the prior, and they closely bracket zero for virtually all values of the data confidence. This suggests that one reason why most studies of money demand include more than one interest rate is that only by so doing does the feasible parameter space become sufficiently large that researchers can find a specification that confirms their prior belief of a significant and negative interest rate effect in money demand.[9]

The two specifications considered above were both static, including only contemporaneous values of both focus and doubtful variables. Much of the literature has placed a strong emphasis on the importance of dynamic behavior in money demand, and a

[9]Many studies report intensive searches to find the "right" interest rate or the best combination of interest rates. A frequent contender is ninety-day commercial paper rate (*RCP*). We have also calculated the extreme bounds on the interest elasticity for specifications in which *RCP* is the focus variable and for specifications in which it is included among the doubtful variables together with *RSL*. The results uniformly imply very wide extreme bounds which include zero.

TABLE 2—EXTREME BOUNDS FOR INTEREST ELASTICITY

Specification 1: Sum of Coefficients of *RTB* and *RSL*												
Data Confidence	0.0	0.250	0.500	0.750	0.900	0.950	0.970	0.980	0.990	0.995	0.999	1.00
Upper Bound	−.165	−.034	−.004	0.027	0.058	0.077	0.090	0.100	0.115	0.130	0.161	3.53
Lower Bound	−.165	−.304	−.336	−.370	−.404	−.425	−.439	−.449	−.466	−.482	−.515	−7.73
Specification 2: Focus Variable *RTB*												
Data Confidence	0.0	0.250	0.500	0.750	0.900	0.950	0.970	0.980	0.990	0.995	0.999	1.00
Upper Bound	0.006	.024	.029	.034	.039	.042	.044	.045	.048	.049	.055	2.24
Lower Bound	0.006	−.014	−.019	−.025	−.031	−.034	−.037	−.038	−.041	−.043	−.049	−6.27
Specification 3: Focus Variables $\sum_{i=0}^{2} RTB_{-i}$ and $\sum_{i=0}^{2} RSL_{-i}$												
Data Confidence	0.0	0.250	0.500	0.750	0.900	0.950	0.970	0.980	0.990	0.995	0.999	1.00
Upper Bound	−.177	0.501	0.588	0.682	0.770	0.826	0.863	0.891	0.935	0.976	1.07	3.48
Lower Bound	−.177	−.918	−1.02	−1.12	−1.23	−1.29	−1.33	−1.37	−1.42	−1.47	−1.57	−7.63

wide variety of dynamic specifications are typically considered. To ascertain whether the static nature of the models just considered has any impact on our results we amended the equation by including as explanatory variables the once-lagged, twice-lagged, and three times lagged values of all explanatory variables. Again, the focus variables are *RTB* and *RSL*, and our prior distribution is uninformative about the coefficients of both the current and lagged values of these variables. All other variables are regarded as doubtful, and the prior location for the sum of the coefficients of all lagged values of each of the doubtful variables is assumed to be zero. The extreme bounds for the sum of the coefficients of *RTB* plus those of *RSL*, both lagged and current, are displayed as Specification 3 in Table 2. Obviously the respecification only increases still further the specification uncertainty in the estimate of the interest elasticity of money demand.

These results all support one conclusion: the preponderance of empirical studies of the demand for money which show significant negative interest elasticities reflect the unacknowledged prior beliefs of the researcher and not the information content of the data. Based only on sample evidence and those priors which appear to us to be directly implied by theory, it is next to impossible to say anything about the interest elasticity of money demand. The data are such that a modestly energetic specification search will give back almost whatever interest elasticity one wishes to extract, particularly if more than one interest rate is included and if the specification search involves extended tinkering with dynamic effects.

IV. Identification and Simultaneity

A determination that a regression is well specified must be made on a priori grounds. In our case, least squares estimation of the demand for money is justified only if there is no feedback from the error to the principal explanatory variables: the interest rate and *GNP*. Since the Federal Reserve chooses the setting of the interest rate partly or largely in order to influence the behavior of the money stock, and therefore largely in response to past and current levels of the money stock, there appears in fact to be a strong prior presumption for the existence of correlation between the explanatory variables and the error, implying that the estimate of the coef-

icients of the focus variables will be inconsistent. Despite this fact, the overwhelming majority of studies of money demand rely primarily or exclusively on ordinary least squares estimators and, surprisingly, the proportion of studies that do not even mention the simultaneity problem appears to be increasing.

Those studies which do at least discuss the problem may be grouped into three classes. The first consists of those studies which bring up the simultaneity problem only to dismiss it in a perfunctory manner on the grounds that other investigators (usually Goldfeld, 1973) have concluded that parameter estimates are not much affected when correction for simultaneity is made, implying that least squares estimation is justified. The second group adopts a position that is interesting on methodological grounds. In these studies it is acknowledged that simultaneity may be a serious problem, but it is contended also that results derived as if it were nonexistent are still of interest (compare, for example, Eugene Fama, 1979a, b). Hence the need seriously to evaluate alternative possible treatments of simultaneity is obviated.

The third group, consisting of those studies which explicitly discuss simultaneity, however briefly, is of primary interest for our purpose. Laidler (1977) devoted four pages in a 182-page book to discussion of identification and simultaneity. After pointing out that the data will not in general identify either demand or supply, he argued that they will in fact identify demand if

> ... the supply function of money shifts independently of the demand-for-money function, [i.e., if] the supply-of-money function contains at least one variable that does not appear in the demand function. It is not hard to establish that this is the case, for the level of reserves made available by the central bank to the commercial banking system figures prominently in any theory of the supply of money and does not appear in any theory of the demand for money. There is also ample evidence that this variable shifts around over time, permitting us to be sure that we can obtain observations taken at different points on the demand-for-money function. [pp. 115–16]

The simplicity and directness of this argument are disarming, and one wishes that it could be accepted. But the condition that supply shifts independently of demand means that reserves must be excluded not only as an explicit explanatory variable on the demand side (Laidler is surely correct that it can reasonably be so excluded), but also as an explanatory variable for the unobserved determinants of money demand. Specifically, it is necessary to assume that the covariance of reserves and the error in money demand are zero. In the absence of this or some other assumption, neither the parameters of money demand nor the covariance of the error with reserves is identified, as may readily be verified. But surely the assumption that random shifts in money demand are not at least partially accommodated by the Federal Reserve is even less plausible than the assumption that such shifts do not result in an interest rate response. In the rest of his book Laidler's discussion of simultaneity is confined to the usual pro forma observation that it does not appear to be a problem because studies which employ simultaneous equations estimators reach conclusions that do not differ greatly from those of studies using ordinary least squares.

Let us now consider the study most often cited as justification for the abbreviated treatment of simultaneity in the large majority of recent empirical studies of money demand: Goldfeld (1973). Here again the discussion of simultaneity problems is agreeably brief; three pages in an article of sixty-one pages suffice for the discussion of both simultaneous equations problems and serial correlation of residuals. The reader is told that "... a casual interpretation of the evidence suggested that simultaneity was not likely to be important..." (p. 621). The suggestion here is that there is some way to interpret the data or the regressions directly to ascertain whether simultaneity problems exist; on the usual view, the determination must be made on a priori grounds. However, Goldfeld also checked these "rough impressions" by choosing a "plausible set of instru-

ments" and reestimating by two-stage least squares. He found that the estimated equation was not greatly altered. Now it is obvious that this conclusion by itself suggests only that ordinary least squares and the instrumental variables estimator have approximately the same inconsistency, not that either is necessarily consistent. We are led to inquire whether the case for believing that Goldfeld's two-stage least squares estimator is consistent is any stronger than the corresponding case for ordinary least squares.

An instrumental variables estimator is approximately consistent if the covariance of the instruments with the error is small relative to the covariance with the observed explanatory variables, a determination which can be made only on a priori grounds since the error is unobservable. In a footnote the reader learns that the "plausible" instruments were population, the discount rate, state and local government spending, and the lagged money stock. It is altogether unclear why we should believe that state and local government spending and especially population covary more with the interest rate than with the error. There is no doubt that the discount rate covaries with the Treasury bill rate, but it may well also be highly correlated with the error. On the traditional interpretation the Federal Reserve uses the discount rate as an instrument to influence the money stock, implying that it will surely respond to random shifts in money demand. If, on the other hand, the discount rate is viewed as merely following the movement of open market rates passively, as is more realistic in recent years, it should be subject to the same inconsistency as open market rates themselves. Similarly, the lagged money stock is a suitable instrument only if it can be argued on prior grounds that its correlation with the error is low relative to that with the interest rate, a question which Goldfeld does not address. We see no reason for supposing that the lagged money stock may serve as an instrument in estimating demand any more than of supply. We are left unconvinced that money demand has been consistently estimated.

Sometimes least squares estimation of money demand is justified on the grounds that the Federal Reserve uses an interest rate as its instrument in the conduct of short-run monetary policy, supposedly implying that the interest rate may be taken exogenous. In its simplest form, this argument rests on an elementary confusion between two senses in which the term "exogenous" is used in the economics literature. In macroeconomic theory a variable, the level of which is set by government as an implementation of economic policy, is represented analytically as an exogenous variable; that is, as a variable not determined within the model, since the latter explains only the behavior of the private sector. Analysis then centers on the effect of policy changes, represented by shifts in the exogenous policy variable(s), on endogenous variables. The definition of exogeneity relevant for statistical estimation, however, is entirely different: a variable in a regression is statistically exogenous only if it is independent (in the probability sense) of the unobserved explanatory variables. Whether a variable which is exogenous in the former sense is also exogenous in the latter and relevant sense depends on how government policy is in fact conducted; that is, on the nature of the government's policy rule. Thus the mere fact that under a "money-market conditions" operating procedure the Federal Reserve formulates policy in terms of an interest rate setting obviously does not by itself justify the assumption that the interest rate is statistically exogenous, and that therefore the demand for money can with validity be estimated by least squares.

We do not suggest that all analysts who have dismissed simultaneity problems by referring to the Federal Reserve's money-market conditions operating procedure are unaware of the elementary point just made, although it is clear that some are. Nonetheless, surprisingly, we do not know of any clear discussion in the literature of just what must be assumed about the Federal Reserve's policy rule if least squares estimation of money demand equations is to be justified (however, see our discussion of the question in the following section). Most treatments, on the contrary, are extremely vague at best. Consider, for example, Laidler's 1980 discussion:

> I believe that many would argue that in the United States, the actual conduct of policy in recent years has in fact been such as to make it appropriate to think of the money supply and the base as responding to demand side factors, and hence, to model the short-run dynamics of the demand for money function in the conventional way utilized so far in this paper [i.e., taking the money stock as the dependent variable]. They would defend the view in the following way. Whatever changes there may or may not have been in the targets and indicators of monetary policy since, shall we say, 1953, its instruments have consistently been interest rates. The monetary authority has attempted to achieve whatever may have been its ends by standing ready to buy and sell government securities at a given price (although not necessarily a pegged price). If over any reasonably short period, say a quarter, real income and prices may be regarded as predetermined, and if the monetary authority, and hence the banking system, stands ready to buy and sell securities at a given price, then there is no obstacle to the economy as a whole adjusting its money holdings towards a desired level at a pace of its own choosing. Given this view of the money supply process, the conventional stock adjustment approach to estimating the demand for money function is correctly specified for the United States, whatever may be the drawbacks to the use of such a specification for other times and places. [pp. 237–38]

First, it is not clear what Laidler intended in distinguishing between a "given" price and a "pegged" price. Second and more important, the introduction of the question of whether or not explanatory variables for the money stock are predetermined is altogether mysterious; the relevant question is whether they are statistically exogenous, not predetermined, and one condition is neither necessary nor sufficient for the other.[10]

[10]For discussions of exogeneity, and of the distinction between exogeneity and predeterminedness, see Robert Engle, David Hendry, and Jean-François Richard, and Rodney Jacobs, Leamer, and Michael Ward.

Laidler went on to consider an alternative representation of financial market behavior, based loosely on Karl Brunner and Allan Meltzer's "credit market hypothesis," which appeared to Laidler to suggest that the money stock rather than interest rates may be taken as statistically exogenous.[11] In that case the appropriate estimating procedure would be to regress an interest rate measure on the money stock and the other explanatory variables, instead of taking the money stock as the dependent variable, and then solve the resulting estimated equation to obtain a consistently estimated money demand equation written in the usual manner.

If one is not certain which direction of normalization is more likely to eliminate simultaneity problems, it would appear reasonable to try both normalizations and ascertain how much difference the direction of normalization makes for the parameter estimates of interest. If the estimates are not too different, the presumption would appear to be that simultaneity problems are not serious. William Poole (1970b) proposed just this approach, remarking that "it can be hoped" that the resulting estimates will bracket the true parameter value (p. 487). Goldfeld (1973) also suggested that estimating money demand in the renormalized form and comparing the results with the original estimates would "shed some light" (p. 622) on the simultaneity question. Now, it is well known that bounds on estimates of variables which are measured subject to error can be obtained in this manner, and this appears to be what Poole and Goldfeld were thinking of, but it is not clear why Poole and Goldfeld think that the simultaneity problem is analogous. In the following section, however, we show that in the case under consideration the probability limits of the parameter estimates under the alternative normalizations do not in fact bracket the true parameter in general.

[11]There is a curious lack of parallelism in Laidler's argument. The operative element of the "money market hypothesis" that is held to justify the specification of interest rate exogeneity is that the Federal Reserve responds passively to shifts in money demand. However, Brunner and Meltzer defined the money market hypothesis and credit market hypothesis as rival theories of how financial markets operate, an entirely different matter.

Thus we remain uninstructed on how the renormalization estimation procedure considered by Poole, Goldfeld, and Laidler sheds any light at all on the simultaneity question.

V. Identification and Simultaneity: Alternative Treatments

We have criticized the empirical literature on money demand for minimizing the seriousness of simultaneity problems and for representing obviously inadequate corrections as in fact adequate. The question arises whether any better treatment is available. In this section we consider several apparently reasonable approaches to the problem, but conclude that they are in fact no more plausible than the remedies analyzed and rejected in the preceding section. We conclude that there is no obvious way to formulate models of equilibrium in financial markets in which the demand for money is identified.

Suppose that the demand for money is

$$m=\alpha r+u, \tag{4}$$

where m, the money stock, and r, the interest rate, are both measured as deviations from means, and u is an error. A money supply function may be written most simply as

$$r=\beta m+v, \tag{5}$$

which represents both the money supply function of commercial banks and the response function of the Federal Reserve. The model (4) and (5) is evidently unidentified. To identify the demand equation we must find some variable that shifts supply but can be excluded from the demand relation on prior grounds and is uncorrelated with the error in demand. Most of the obvious candidates (such as reserves, as we pointed out in the preceding section) fail the latter condition. Such lagged endogenous variables as the lagged money stock clearly enter as determinants of the Federal Reserve's response function, but again they cannot plausibly be excluded from the demand side either explicitly as observable explanatory variables for the demand for money or implicitly through the time dependence of the error.

Estimation of disaggregated money demand equations has been suggested as one means of eliminating feedback between the errors and the interest rate. Since the Federal Reserve estimates several major components of the money stock through the Demand Deposit Ownership Survey, disaggregated estimation is feasible.[12] Let us determine what must be assumed in order that least squares estimation of sector demand equations yield a consistent estimate of the interest elasticity coefficients. Suppose the demand for money in the jth sector is

$$m_j=\alpha_j r+w+u_j, \tag{6}$$

where w is an error common to all sectors and u_j is the shock to the jth sector. Assume that the supply relation is of the form

$$r=\beta\sum_j m_j/n+v \tag{7}$$

where n is the number of sectors. For the sake of the argument, suppose that we can somehow assume that w, v and the u_j are all independently distributed with zero means and variances σ_w^2, σ_v^2, and σ_j^2. If $\hat{\alpha}_j$ is the least squares estimate of α_j in (6), we have that

$$plim(\hat{\alpha}_j)=\alpha_j+cov(w+u_j,r)/var(r). \tag{8}$$

From (6) and (7) it is immediate that

$$cov(w+u_j,r)=\beta\left(\sigma_w^2+\sigma_j^2/n\right)\Big/\left(1-\beta\sum_j\alpha_j/n\right) \tag{9}$$

while

$$var(r)=\left(\beta^2\left(\sigma_w^2+\sum_j\sigma_j^2/n^2\right)+\sigma_v^2\right)\Big/\left(1-\beta\sum_j\alpha_j/n\right)^2. \tag{10}$$

Substituting (9) and (10) into (8), we obtain finally

$$plim(\hat{\alpha}_j)=\alpha_j+\beta\left(\sigma_w^2+\sigma_j^2/n\right)\left(1-\beta\sum_j\alpha_j/n\right)\Big/\left(\beta^2\left(\sigma_w^2+\sum_j\sigma_j^2/n^2\right)+\sigma_v^2\right).$$

[12] See Helen Farr, Richard Porter, and Eleanor Pruitt for discussion of the Demand Deposit Ownership Survey.

Obviously even if w, v, and the u_j are independently distributed, ordinary least squares estimation is inconsistent ($1-\beta\Sigma_j\alpha_j/n\neq 0$ is a condition for the existence of a solution to the model). In order to insure consistency it must be assumed both that σ_w^2 equals zero (i.e., that the sector shocks have no common component) and that there are many sectors (n is large). Since the number of sectors for which data are collected in the Demand Deposit Ownership Survey is only four, and since the random shocks in sector demands cannot reasonably be assumed to have no common component, it appears unrealistic to hope that disaggregated estimation will provide a ready resolution to identification and simultaneity problems.

Identification may be sought from prior restrictions on the Federal Reserve's response function. First, as noted in the preceding section, it has been suggested that the assumed existence of a money market conditions control procedure may be used to justify ordinary least squares regression with the money stock as the dependent variable. Under the monetary control procedure in use up to October 1979 the instruction from the Federal Open Market Committee to the Federal Reserve Bank of New York consisted of a setting for the interest rate which was to be adhered to until the next FOMC meeting unless a proviso clause related to the monetary aggregates becomes operative. If 1) the existence of the proviso clause is ignored, 2) the data interval is assumed to be the month rather than the quarter (since the FOMC meets three times within the quarter and generally revises the instrument setting each time), 3) the Federal Reserve's control procedure is viewed as mechanically implemented rather than subject to large judgmental input, as is in fact the case, and 4) the response of commercial banks to current shocks can be ignored, then the response function may be written as

$$r_t=\beta\phi_{t-1}+v_t, \tag{11}$$

Here ϕ_{t-1} is the set of determinants of the interest rate setting, which by assumption does not include any currently determined variables. Here there is no direct feedback from the error in money demand to the interest rate, since the observable determinants of the interest rate in the response function are not affected by the current error in money demand. But ordinary least squares is still inconsistent unless it is also assumed that the errors in demand and supply are independent (otherwise r and u will be correlated) and that the error in demand is not autocorrelated. If u is autocorrelated and if m_{t-1} is a component of ϕ_{t-1}, as is surely the case, the current error in money demand will be correlated with ϕ_{t-1} and hence with the interest rate even though there is no direct causal link between them. Again, the collection of assumptions required to justify the usual estimating procedure for the money demand equation is formidable.

In the preceding section we noted that reversing the direction of normalization has been suggested as a procedure that might "shed light" on the simultaneity question in estimating money demand equations. We are led to investigate the conditions under which the estimates from the alternative normalizations bracket the true parameter in the probability limit. Let us then define $\hat{\alpha}$ as the estimated interest elasticity when the money stock is taken as the dependent variable in a least squares regression, and $\hat{\hat{\alpha}}$ to be the estimated interest rate elasticity when the interest rate is the dependent variable (i.e., when the money stock is included as an explanatory variable, but the resulting estimated equation is resolved for the money stock). The question is whether $plim(\hat{\alpha})$ and $plim(\hat{\hat{\alpha}})$ bracket α in general, and if they do not do so in general what conditions are required to assure the conclusion. It is immediately apparent that without prior restrictions on the form of the demand and supply equations the property will not obtain. Consider the supply-demand pair

$$m=\alpha r+u \text{ (demand)}$$
$$m=\beta r+v \text{ (supply)}$$

or the pair

$$m=\alpha_1 r+\alpha_2 z+u \text{ (demand)}$$
$$m=\beta_1 r+\beta_2 z+v \text{ (supply)}$$

where z is an exogenous explanatory variable

(or a vector of such variables) entering the supply and demand equations. The symmetry of these supply-demand pairs implies that $\hat{\alpha}$ and $\hat{\hat{\alpha}}$ can be associated just as well with the interest-elasticity of supply as with that of demand. It follows trivially that no inference about either α, β, α_1, or β_1 can be made from the models as specified. Thus we have immediately that there is nothing to be learned by comparing the interest rate elasticities estimated from alternative normalizations in the absence of prior exclusion restrictions or other identifying assumptions.

The obvious system to consider is

$$(12) \qquad m=\alpha r+u \text{ (demand)}$$

$$(13) \qquad m=\beta_1 r+\beta_2 z+v \text{ (supply)}$$

in which the exogenous variable z is assumed to be excluded from demand on prior grounds. Then we have

$$\hat{\alpha}=\sum mr/\sum r^2 \text{ and } \hat{\hat{\alpha}}=\sum m^2/\sum mr.$$

In this system it happens to be possible to show that $plim(\hat{\alpha})$ and $plim(\hat{\hat{\alpha}})$ do in fact bracket α under the prior restrictions that α and β_1 are negative. To do so, solve (12) and (13) for their reduced forms and verify that

$$(14) \quad plim(\hat{\alpha})=\left(\sigma_z^2\beta_2^2\alpha+\sigma_u^2\beta_1+\sigma_v^2\alpha\right) / \left(\sigma_z^2\beta_2^2+\sigma_u^2+\sigma_v^2\right)$$

$$(15) \quad plim(\hat{\hat{\alpha}})=\left(\sigma_z^2\alpha^2\beta_2^2+\sigma_u^2\beta_1^2+\sigma_v^2\alpha^2\right) / \left(\alpha\sigma_z^2\beta_2^2+\sigma_u^2\beta_1+\sigma_v^2\alpha\right).$$

Now it is evident from (14) and (15) that $plim(\hat{\alpha})\leqslant\alpha$ iff $\beta_1\leqslant\alpha$, while $\alpha\leqslant plim(\hat{\hat{\alpha}})$ iff $\alpha\beta_1\leqslant\beta_1^2$. Assuming that α is negative, the condition $\beta_1\leqslant\alpha$ assures that β_1 is negative as well. Consequently, cancelling β_1 from the inequality $\alpha\beta_1\leqslant\beta_1^2$ reverses its sense, and therefore reduces it to $\beta_1\leqslant\alpha$, which we already have. Thus $plim(\hat{\alpha})\leqslant\alpha\leqslant plim(\hat{\hat{\alpha}})$ will be satisfied if $\beta_1\leqslant\alpha<0$. Similarly, $plim(\hat{\hat{\alpha}})\leqslant\alpha\leqslant plim(\hat{\alpha})$ will be satisfied if $\alpha\leqslant\beta_1<0$. It follows that, as long as we can assume that both α and β_1 are less than zero, the two probability limits will in fact bracket the true parameter, as we required to demonstrate. We have a strong prior belief that α is negative, but β_1 cannot be signed on prior grounds. To the extent that β_1 reflects commercial bank behavior, a positive sign is indicated; however, it is likely that β_1 reflects primarily the Federal Reserve response function rather than commercial bank behavior. Even assuming optimal money stock control by the Federal Reserve the response function may be either positively or negatively sloped, depending on the coefficients and error variances of the model (see Poole, 1970b, or LeRoy and David Lindsey, for example). But the major point is that to construct the proof it was necessary to adopt an identifying restriction on prior grounds. If such a restriction is available (an assumption we are not willing to adopt), then it makes more sense simply to estimate consistently in the first place than to obtain estimated bounds on α via the renormalization estimation procedure.

We conclude by considering the implications of assuming that the Federal Reserve's control rule may be given an optimal interpretation. This assumption imposes restrictions linking the parameters of the response function with those of the demand equation, and it is reasonable to explore whether the latter may not be identified thereby. Suppose that the money demand equation is described by the transfer function

$$(16) \qquad m_t=\alpha r_{t-n}+\sum_{j=0}^{\infty} a_j u_{t-j},$$

where the u_t are white noise innovations. This specification assumes that the interest rate affects the demand for money with a lag of n periods; in the cases considered above n equals zero, but it is desirable to achieve greater generality here. Assume that the Federal Reserve wishes to vary r_t, the instrument, so as to minimize an objective function of the form $\Sigma_t(1+\rho)^{-t}(m_t-m_t^*)^2$, where $\{m_t^*\}$ is some preassigned "optimal" trajectory for the money stock. Under lagged reserve accounting the assumption that the Federal Reserve ignores reserves and con-

structs an optimal monetary control rule from the money demand equation alone involves no loss of generality.[13] The certainty equivalence principle ensures that the loss will be minimized if the interest rate is varied so that

$$E_t(m_{t+n}) = m^*_{t+n}. \tag{17}$$

From (16) we have that

$$m_{t+n} = \alpha r_t + \sum_{j=0}^{\infty} a_j u_{t+n-j}, \tag{18}$$

implying that

$$E_t(m_{t+n}) = \alpha r_t + \sum_{j=n}^{\infty} a_j u_{t+n-j}. \tag{19}$$

By assumption, r_t is set so that $E_t(m_{t+n}) = m^*_{t+n}$, so (19) becomes

$$m^*_{t+n} = \alpha r_t + \sum_{j=n}^{\infty} a_j u_{t+n-j} \tag{20}$$

for optimal r_t. In such a world, which parameters of the demand equation will be identifiable? From (18) and (20), the observed money stock will fluctuate around the optimum according to

$$m_{t+n} = m^*_{t+n} + \sum_{j=0}^{n-1} a_j u_{t+n-j}, \tag{21}$$

implying that the first n of the a_j can be estimated. However, from (20) the remaining a_j and α, the interest elasticity of money demand, cannot be identified even if the m^*_t are known. Thus once again we find that the parameter we are concerned with cannot be estimated.

[13] Poole (1970a) showed that under current accounting an optimal monetary control rule generally involves both reserves and interest rates. The reason reserves enters the optimal combination policy is that in general under current reserve accounting changes in reserves provide information about contemporaneous shifts in money demand. Under lagged reserve accounting, however, changes in reserves demand depend primarily on changes in money demand two weeks earlier. But the money stock two weeks earlier is itself observable, or nearly so, implying that reserves no longer provide information useful for money stock control. This fact implies that an optimal combination policy coincides with a pure interest rate policy, and thus the optimal monetary control rule may be constructed from the money demand equation alone (see LeRoy).

VI. Conclusion

In this paper we have argued two largely independent points. The first is that the negative interest elasticity of money demand reported in the literature represents prior beliefs much more than sample information. The second is that the treatment of simultaneity in the literature is totally inadequate. Thus we are left with the conclusion that we are unpersuaded by existing attempts to estimate a money demand equation, but we are unable to supply an attractive alternative. This outcome is admittedly unsatisfactory, and we do not offer it as a final conclusion. But we believe that no progress can be made in estimating such structural macroeconomic equations as that for the demand for money until we rid ourselves of the habits of data mining, of building in priors through selective reporting, and of casually adopting what Christopher Sims has called "incredible" identifying assumptions to dispose of simultaneity problems.[14]

[14] For an early criticism of the latter practice, see the classic paper of T. C. Liu.

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The Economics of Superstars

By SHERWIN ROSEN*

The phenomenon of Superstars, wherein relatively small numbers of people earn enormous amounts of money and dominate the activities in which they engage, seems to be increasingly important in the modern world. While some may argue that it is all an illusion of world inflation, its currency may be signaling a deeper issue.[1] Realizing that world inflation may command the title, if not the content of this paper, quickly to the scrap heap, I have found no better term to describe the phenomenon. In certain kinds of economic activity there is concentration of output among a few individuals, marked skewness in the associated distributions of income and very large rewards at the top.

Confidentiality laws and other difficulties make it virtually impossible to obtain systematic data in this field. However, consider the following:

(i) Informed opinion places the number of full-time comedians in the United States at approximately two hundred. This is perhaps a smaller number than were employed in vaudevillian days, though it hardly can be maintained that the demand for (intended) comic relief is in a state of secular decline. Some of the more popular performers today earn extraordinary sums, particularly those appearing on television. The capacity for television to produce high incomes is also manifest in the enormous salaries paid to network news broadcasters.

(ii) The market for classical music has never been larger than it is now, yet the number of full-time soloists on any given instrument is also on the order of only a few hundred (and much smaller for instruments other than voice, violin, and piano). Performers of first rank comprise a limited handful out of these small totals and have very large incomes. There are also known to be substantial differences in income between them and those in the second rank, even though most consumers would have difficulty detecting more than minor differences in a "blind" hearing.

(iii) Switching to more familiar territory, sales of elementary textbooks in economics are concentrated on a group of best sellers, though there exists a large number of very good and highly substitutable alternatives in the market (the apparent inexhaustable supply of authors willing to gamble on breaking into the select group is one of the reasons why so many are available). A small number of graduate schools account for a large fraction of Ph.D.s. A relatively small number of researchers account for a large fraction of citations and perhaps even articles written.

Countless other examples from the worlds of sports, arts and letters, and show business will be well known to readers. Still others can be found in several of the professions. There are two common elements in all of them: first, a close connection between personal reward and the size of one's own market; and second, a strong tendency for both market size and reward to be skewed toward the most talented people in the activity. True, standard theory suggests that those who sell more generally earn more. But that principle applies as well to shoemakers as to rock musicians, so something more is involved. In fact the competitive model is virtually silent about any special role played by either the size of the total market or the amount of it controlled by any single person, because products are assumed to be undifferentiated and one seller's products are assumed to be as good as those of any other.

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[1]That escalation is not confined to wars and prices is established by the fact that Stars would have sufficed not long ago. Academics have a certain fondness for Giants, while businessmen prefer Kings. Obviously there is a fair bit of substitution among all these terms in depicting related data in different contexts.

The elusive quality of "box office appeal," the ability to attract an audience and generate a large volume of transactions, is the issue that must be confronted. Recognition that one's personal market scale is important in the theory of income distribution has a long history, but the idea has not been developed very extensively in the literature.[2] I hope to fill in some of the gaps in what follows.

The analytical framework used is a special type of assignment problem, the marriage of buyers to sellers, including the assignment of audiences to performers, of students to textbooks, patients to doctors, and so forth. Rest assured that prospective impresarios will receive no guidance here on what makes for box office appeal, sometimes said to involve a combination of talent and charisma in uncertain proportions. In the formal model all that is taken for granted and represented by a single factor rather than by two, an index q labeled talent or quality. The distribution of talent is assumed to be fixed in the population of potential sellers and costlessly observable to all economic agents. Let p be the price of a unit of service (for example, a performance, a record, a visit, etc.) and let m be the size of the market, the number of "tickets" sold by a given seller. Then an overall market equilibrium is a pair of functions $p(q)$ and $m(q)$ indicating price and market size of sellers of every observable talent and a domain of q such that: (a) all sellers maximize profit and cannot earn larger amounts in other activities, and (b) all buyers maximize utility and cannot improve themselves by purchasing from another seller.

Properties of sellers' maximum net revenue functions, $R(q)$, will have special interest. Specifically, convexity of this function describes much of the observable consequences of Superstars. Since $R(q)$ is the transformation that takes the distribution o talent to the distribution of rewards, convex ity implies that the income distribution i stretched out in its right-hand tail compare to the distribution of talent. Hence a genuin behavioral economic explanation is provide for differential skew between the distribu tions of income and talent, a problem tha has been an interesting and important preoc cupation of the literature on income distribu tion down through the years.[3] Convexity o $R(q)$ literally means that small differences i talent become magnified in larger earning differences, with great magnification if th earnings-talent gradient increases sharpl near the top of the scale. This magnificatio effect is characteristic of the phenomeno under consideration.

Convexity of returns and the extra skew i imparts to the distribution of earnings can b sustained by imperfect substitution amon different sellers, which is one of the hall marks of the types of activities where Super stars are encountered. Lesser talent often is a poor substitute for greater talent. The worse it is the larger the sustainable rent accruin to higher quality sellers because demand for the better sellers increases more than proportionately: hearing a succession o mediocre singers does not add up to a single outstanding performance. If a surgeon is 10 percent more successful in saving lives than his fellows, most people would be willing to pay more than a 10 percent premium for his services. A company involved in a $30 million law suit is rash to scrimp on the legal talent it engages.

Imperfect substitution alone implies convexity and provides a very general explanation of skewed earnings distributions which applies to myriad economic service activities.

[2]Albert Rees is a good introduction to the size distribution of income. The selectivity effects of differential talent and comparative advantage on the skew in income distributions are spelled out in my 1978 article, also see the references there. Melvin Reder's survey touches some of the issues raised here. Of course social scientists and statisticians have had a long standing fascination with rank-size relationships, as perusal of the many entries in the *Encyclopedia of the Social Sciences* will attest.

[3]Few economic behavioral models exist in the literature. On this see Harold Lydall. Jacob Mincer has shown that investment can produce skewness through the force of discounting, and established that as an important source of skewness empirically. Learning is not treated here because those issues are well understood, whereas the assignment problem has received little attention. Some recent works, but with different focus and emphasis than is discussed here, are Gary Becker (1973), David Grubb, and Michael Sattinger.

However, preferences alone are incapable of explaining the other aspect of the Superstar phenomenon, the marked concentration of output on those few sellers who have the most talent. This second feature is best explained by technology rather than by tastes.[4] In many instances rendering the service is described as a form of joint consumption, not dissimilar to a public good. Thus a performer or an author must put out more or less the same effort whether 10 or 1,000 people show up in the audience or buy the book. More generally, the costs of production (writing, performing, etc.) do not rise in proportion to the size of a seller's market.

The key difference between this technology and public goods is that property rights are legally assigned to the seller: there are no issues of free riding due to nonexclusion; customers are excluded if they are unwilling to pay the appropriate admission fee. The implied scale economy of joint consumption allows relatively few sellers to service the entire market. And fewer are needed to serve it the more capable they are. When the joint consumption technology and imperfect substitution features of preferences are combined, the possibility for talented persons to command both very large markets and very large incomes is apparent.

A theory of the assignment of buyers to sellers is required to make these ideas precise. The demand and supply structure of one such model is set forth in Sections I and II. The nature of market equilibrium and its implications for income and output distributions are discussed in Sections III and IV. Comparative static predictions of the model are sketched in Section V and conclusions appear in Section VI.

[4]Milton Friedman proposed a model based on preferences for risk taking, but did not explain why or how the market sustains the equilibrium *ex post* with few sellers earning enormous incomes (for example, why the losers in the lottery rest content with such low incomes if they have the same talents as the winners). Issues of uncertainty that make these elements of supply more interesting are abstracted from here. A model of prizes based on effort-incentive monitoring and the principal agency relation is found in my article with Edward Lazear.

I. Structure of Demand

Imperfect substitution among quality differentiated goods in the same product class arises from indivisibilities in the technology of consumption. No satisfactory analytical specification exists in the literature, because indivisibilities lead to nonadditivities in preference relations which are analytically intractable.[5] Yet some specific model is required to make any progress on this problem. My solution to this dilemma is to adopt a smooth quantity-quality substitution technology and introduce the indivisibility through a fixed cost of consumption per unit of quantity. Consumers' attempts to minimize consumption costs gives an extra competitive advantage to higher quality sellers. However, it is a surprising implication of the analysis that this form of indivisibility is not crucial to the central conclusions, so that true nonadditivities would only strengthen the argument.

Assume the consumer has a well-behaved weakly separable utility function $u = u(x, g(n, z))$, where x is a composite commodity and $y = g(n, z)$ has the natural interpretation of consumption of "services" of the type in question. n is the quantity purchased, a measure of exposure to a seller, such as a patient visit, a performance, etc.; and z is the quality of each unit of exposure. Quantity-quality substitution requires that $g(\cdot)$ is increasing in both of its arguments and that $\partial^2 g/\partial n \partial z > 0$.

This specification has the virtue of being simple, at the cost of ignoring some details and not being perfectly general. The definitions of markets are left somewhat vague: for example, for some purposes it is sufficient to think about the market for novels as a whole and for others distinguishing between mysteries, romances, and so forth is necessary. This is simply treated by allowing y to be a vector and is therefore ignored. There are several dimensions to quantity in any specific application which might be treated in a simi-

[5]Some of the thorny issues of primitives in problems of product differentiation are discussed from the point of view of the theory of measurement by Manuel Trajtenberg.

lar manner. For example, most people do not purchase more than one copy of an author's book but may buy several different books written by the same author. Or there may be preferences for variety. But these considerations are less than compelling in markets for professional services where direct personal contact between buyers and sellers is required. Preferences for variety per se cannot be treated in a quantity-quality substitution model, and since the generalization of increasing the dimensionality of exposure is clear enough in any given case, it is ignored too. It is doubtful whether the general nature of the results are greatly affected by these simplifications.

A cardinal measure of quality or talent must rely on measurement of actual outcomes. Taken to extreme, this view would define the talent distribution as the realized output or income distribution. However, that goes too far because it ignores the fact that more talented people typically command greater cooperating resources in producing observed outcomes and it refers to all consumers as a group rather than to any one of them. The service flow y is a natural personal outcome measure in this case and is the prime candidate for scaling talent, so long as n is held constant in the imputation to obtain the right *ceteris paribus* conditions. Still, the measure is strongly dependent on n unless $g(n,z)$ is multiplicatively separable. To avoid ambiguity I restrict $g(n,z)$ to the form $zf(n)$, so that relative talent is defined independently of n (since y is the product of a function of n and another function of z, talent can always be rescaled to be the function of z itself, for example, if $y=f_1(z')f_2(n)$, change the scaling of z' by defining $z\equiv f_1(z')$). The properties of $f(n)$ play no important role in this analysis, so it is assumed to be linear. Therefore $y=nz$, which is the familiar efficiency units specification. This is a very strong form of substitution which obviously works in the direction of spreading sales around all qualities of sellers, not concentrating them among the top, and is a weak specification in that sense.

The cost of one unit of service of a given quality is its price $p(z)$ plus a fixed cost s. For example, if each unit requires t hours and the wage rate is w, then $s=tw$. Measuring prices in units of x, the budget constraint is

$$(1)\qquad I=x+(p+s)n$$
$$=x+[(p+s)/z]y=x+vy,$$

where I is full income and v is the full price of services directly implied by the multiplicative specification $y=nz$ (herein lies the analytical value of that assumption).

Marginal conditions for consumer choice are

$$(2)\qquad u_y/u_x=dp(z)/dz \text{ for } z;$$
$$u_y/u_x=(p+s)/z \text{ for } n.$$

Combining these two, choice of z solves

$$(3)\qquad dp/dz=p'(z)=(p+s)/z.$$

Choice of n follows from the requirement that the marginal rate of substitution between y and x equals the relative marginal cost $v=(p+s)z$. The schedule $p(z)$ is the same for all buyers. It maps the talent of a seller into the unit price charged for that quality of service. Therefore optimal choice of z in (3) depends only on s and not on the form of the utility function under the separability assumption. Condition (3) balances larger direct costs of greater talent against larger indirect costs of greater quantity and lesser talent. For example, customers with larger s prefer more talented sellers to economize on consumption time in this specification. Finally, all effects of intensity of preferences are absorbed in choice of the quantity consumed, given the optimum value of z determined by condition (3).

Because it plays an important role in the analysis below, suppose the equality in (3) held for all possible values of z, not just for one of them. Evidently that occurs only if $p(z)$ happens to follow a definite functional form; the one satisfying (3) interpreted as a differential equation for all z. Integrating and simplifying equation (3) yields

$$(4)\qquad p(z)=vz-s.$$

The full price v is the constant of integration.

since $v=(p+s)/z$ by definition. If market prices line up as in (4), the consumer is indifferent among all values of z that appear on the market, since (3) is an identity. Therefore (4) must be a price-talent indifference curve, an equalizing difference function, showing the maximum amount the customer is willing to pay for alternative values of z at a given utility index. The larger is v, the smaller the utility index. Finally, if (4) does in fact hold true in the market, too, then both equations in (2) reduce to $u_y/u_x=v$, so that y is uniquely determined for the consumer even though z and n are not.

II. Structure of Supply: External and Internal Diseconomies

The economic activities under consideration invariably involve direct contact of buyers with the seller in one way or another. If a competitive market was ever impersonal, this surely is not it. The seller's choice of market size (volume of transactions) amounts to determining the number of contacts to make with buyers. In many cases the technology admits a certain kind of duplication in which the seller delivers services to many buyers simultaneously, as a form of joint consumption. Once the author tells his tale to the publisher, it can be duplicated in writing as many times as desired. A performer appearing on television literally clones his performance to whomever happens to tune in. The services rendered by any seller become more like a kind of public good the more nearly the technology allows perfect duplication at constant cost.

Just as it is difficult to find practical examples of pure public goods in public finance, so too it is difficult to find them here. In fact services of this type are analogous to local public goods, due to ultimate limitations on joint consumption economies. To the extent that the technology is subject to congestion, that is, to external diseconomies of scale, the required analytical apparatus is the theory of clubs rather than the theory of pure public goods.[6] These external diseconomies reflect a type of degradation of services a seller supplies to each of his customers as the number of contacts expands. There are two fundamental reasons for this:

First, in cases where duplication is possible, market expansion ultimately requires using inferior techniques to render the service. It is preferable to hear concerts in a hall of moderate size rather than in Yankee Stadium. Recordings are a superior way of reaching a large audience, but are inferior in quality to live performances with smaller audiences. Furthermore, many of the activities in question involve certain creative elements so the ultimate negative impact of market sizes sometimes can be interpreted as the effect of overexposure and repetition.

Second, the analysis should not be constrained to only those activities where some form of cloning is possible. The general model also applies to cases of one-on-one buyer-seller contact, as is true of professional services. Here the negative effects of personal market scale are caused by limitations on the seller's time. As a doctor's patient load increases, the amount of direct contact time available to any person decreases, waiting time between appointments and in the office increases, and so forth. Nevertheless patients may be willing to trade off service time against quality of service per unit time.

In both cases the quality of service z that appears in consumers' preferences is itself produced by both the quality and size of the market of the seller with whom transactions occur: $z=h(q,m)$, where q is an index of seller talent or quality and $m=m(q)$ is the total number of units sold by a seller of type q. The arguments above imply $\partial z/\partial q=h_q>0$ and $\partial z/\partial m=h_m\leqslant 0$. Furthermore, I assume that $h_{qm}\geqslant 0$: superior talent stands out and does not deteriorate so rapidly with market size as inferior talent does. The importance of this assumption will emerge later on.

Preferences are structured on service flows, which in turn depend upon q and m. Therefore $p=p(q,m)$ is the unit price charged by a seller of quality q selling m units. Competi-

[6] That a doctor's patients or a performer's fans might be considered as a club has intuitive plausibility. The original reference in the theory of public finance is James Buchanan. Eitan Berglas and Berglas and David Pines, present elegant developments of that model.

tion in the market for services implies that the *function* $p(q,m)$ is taken as given by a seller. This market is competitive even though a seller affects the unit price charged by choosing m. The reason for competition in markets of this type is that each seller is closely constrained by other sellers offering similar services. Though sellers of different quality are imperfectly substitutable with each other, the extent of substitution decreases with distance. In the limit very close neighbors are virtually perfect substitutes. Assume there is a regular distribution of talent in the population $\phi(q)dq$. Then potential substitution is generated by both the density ϕ in the neighborhood dq of q and by degradation through larger market size of better quality sellers some distance above q, and the opposite for those some distance below q.

In addition to market size effects on demand, the other factor influencing the output decision is direct cost of production. Let $C(m)$ be out of pocket costs of producing m units, with $C'\geqslant 0$ and $C''\geqslant 0$. There are nondecreasing (marginal) costs of production—internal diseconomies—for the usual reasons, including the fact that here the seller must work harder as m increases. Assume also that all sellers have opportunity cost K of working in this sector compared with the next best alternative, with K independent of q.

A seller of type q chooses $m(q)$ to maximize net revenue

$$(5) \qquad R(q)=p(q,m)m-C(m).$$

Therefore $m(q)$ is chosen to satisfy

$$(6) \quad mp_m(q,m)+p(q,m)-C'(m)=0$$

so long as

$$(7) \qquad 2p_m+mp_{mm}-C''<0$$

and R exceeds K. Equation (6) determines the intensive margin. If $R(q)$ is monotone in q, then free entry determines an extensive margin as well; the value of q, denoted q_l, which satisfies both $R(q_l)=K$ and (7) simultaneously.

In context a more elaborate return specification decomposes the internal margin above into two additional components, one being the size of each act of joint consumption, m_1, and the other being the number of such acts, m_2. In that case the revenue function is

$$(8) \qquad m_2[m_1p(q,m_1,m_2)-C_1(m_1)]-C_2(m_2)$$

where m_1p-C_1 are the "gate" receipts for each event and $C_2(m_2)$ is the cost of increasing the number of events. This avoids some of the dimensionality or units ambiguities in (5), as noted in Section I. If all external diseconomies reside in m_1 alone and not m_2 (so that $p=p(q,m_1)$), then (8) and (5) have very similar implications; only the diseconomy associated with each event is somewhat overcome by expanding their number in formulation (8). This carries over to a case where the external diseconomy of m_2 is small. Otherwise, precise results depend on whether the effect on performance services of m_1 are stronger than those of m_2 and on their interaction. It is simplest to merely think of m in (5) as the product of m_1 and m_2, in those cases where this type of decomposition is applicable.

III. Market Equilibrium

A complete closed market solution is available if all buyers have the same fixed cost s, though possibly different marginal rates of substitution between y and x. In that case it is possible to aggregate total services in a single market, with a unique implicit market price v which contains all the relevant information and acts as a "sufficient statistic." The unit price p charged by a seller of type q is then constrained to follow (4) independent of market supply conditions. Though n and z are not uniquely determined for any consumer, each one has a regular demand function for services y which depends only upon v. These demands in turn can be summed across consumers to obtain the total market demand for services $\Sigma y\equiv Y^d=F(v)$. Since consumers are indifferent between n and z, the composition of services between qualities and quantities are de-

ermined completely by sellers, who maximize profit according to condition (6). Individual supply choices may be aggregated too, his time by integrating the optimum value of zm, the total services a seller supplies to the market, over those values of q which are actually found in the market, weighted by the number of sellers of type q, $\phi(q)$. This sum represents total services supplied to the market, $Y^s = G(v)$. The intersection of supply and demand determines v itself. Given this equilibrium, the internal cross-section price, output, and income distributional structure may be examined in detail.

To find the supply decision of each seller at a given value of v, substitute $z=h(q,m)$ into the equalizing difference function (4). Applying (6) and (7) yields

$$(9)\quad vmh_m(q,m)+vh(q,m)-s-C'(m)=0;$$

$$(10)\quad 2vh_m+vmh_{mm}-C''<0.$$

Differentiate (9) with respect to q:

$$(11)\quad \partial m/\partial q=-v(h_q+mh_{qm})/(2vh_m+vmh_{mm}-C'')>0.$$

Market size increases with q if $h_{qm}>0$. Next differentiate net revenue $R(q)$ in (5) with respect to q, at its maximized value. By the envelope property

$$(12)\quad R'(q)=vmh_q>0.$$

Net revenue is monotonically increasing in talent, since $h_q>0$. Finally, differentiate (12) with respect to q and simplify to obtain

$$(13)\quad R''(q)=v(h_q+mh_{qm})(\partial m/\partial q)+vmh_{qq},$$

where $\partial m/\partial q$ is defined by equation (11). So long as h_{qq} is not sufficiently negative, reward is convex in q.

The market supply of services is easily calculated. Let $m(q;v)$ be the solution to (9). Then the amount of service supplied to the market by a seller of quality q is $h(q,m(q;v))m(q;v)$ and the total amount supplied to the market by all active sellers is

$$Y^s(v)=\int_{q_l(v)}^{\infty} h(q,m(q;v))m(q;v)\phi(q)dq,$$

where $q_l(v)$ is the extensive margin. Differentiate with respect to v:

$$dY^s/dv=-h(q_l,m^l)m^l\phi(q_l)(dq_l/dv)+\int_{q_l}^{\infty} h\left[1+\frac{m}{h}\left(\frac{\partial h}{\partial m}\right)\right]\left(\frac{\partial m}{\partial v}\right)\phi(q)dq,$$

where $m^l=m(q_l;v)$. Condition (9) implies that $1+(m/h)h_m$ is positive. Therefore the second (integral) term in dY/dv is positive. The fact that R is increasing in both q and v from (12) implies that $dq_l/dv<0$, so that the first term is positive as well. Hence there is rising supply price in the service market. It is obvious from Section I that there is falling demand price for services, so a conventional equilibrium is obtained and v is uniquely determined.

A. *Internal Diseconomies*

The cross-section structure of the market equilibrium is most easily established in the case where there are no effects of a seller's market size on service quality.[7] In that case m is not an argument of $h(\cdot)$ and talent is scaled so that $z=h(q)=q$. Now the model has a Ricardian flavor, with differential rent sustained by talent induced product differentiation.

Since $z\equiv q$ the unit price charged by sellers of talent q is increasing linearly in q at rate v, from (4); and since price is higher for the better sellers and cost conditions no less favorable, more talented sellers produce more and have larger markets.[8] Application of (11)

[7]This version of the model has a strong family resemblance to a class of problems previously considered in my 1974 article.

[8]Throughout this paper I make the usual club theory assumptions and ignore indivisibilities requiring an integer number of sellers. This can be problematic when the number of sellers is very small, and raises well-known problems in industrial organization about which I have nothing to contribute. The magnitude of the rent of the lowest rent seller (extensive margin) is the issue. That must be sufficiently small for this analysis to apply.

to this case yields $\partial m/\partial q = v/C'' > 0$. From (12), $R'(q) = vm > 0$, and $R''(q) = v^2/C'' > 0$, from (13). Not only does rent reward increase in talent, but marginal rent reward increases in talent as well. $R(q)$ is convex because both price and quantity increase in q. To see the powerful force of convexity in producing skewness, consider an example where $s=0$ and $C(m)$ is quadratic. Then $m \propto vq$ and both price and quantity increase linearly in q. Therefore, revenue increases in the square of q. In fact $R \propto v^2q^2/2$. A person who is twice as talented as another earns four times more money in this example.[9]

This case is important in showing that the tendency toward skewed rewards arising from convexity of revenues holds under very general circumstances: individuals who, by virtue of superior talent and ability in an activity, can sell their services for higher prices have strong incentives to produce more so long as costs are not perfectly correlated with talent. The increase in both price and quantity with quality implies that talent has a multiplicative effect on reward. It is surprising that the tendency toward skewed rewards is not necessarily dependent on indivisibilities and occurs in the linear efficiency-units case, perhaps the weakest possible specification. However, no relative skew is implied in the distribution of output in this case because there are no interactive effects in that dimension of the problem.

B. *Pure Joint Consumption*

The effect of scale economy on seller concentration is strikingly seen in the extreme case when internal and external diseconomies vanish, when $C(m) \equiv 0$ (nonzero constant marginal costs will do also) and $h_m \equiv 0$, so $z = h(q) = q$. Then there literally is public goods technology and a single seller services the total market in equilibrium. That person

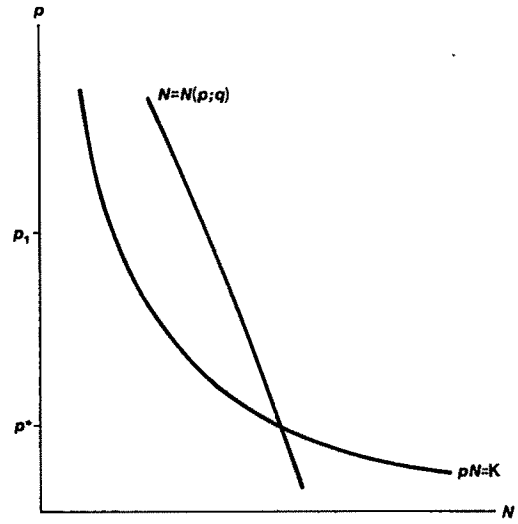

FIGURE 1

is the most talented of all potential sellers. Even though there is one seller, essentially competitive market conditions are maintained by threats of potential entry.

Let $N = N(p,q)$ denote the total market demand for quantity at price p and talent q. If there were several potential sellers of the same talent, only one of them is required to provide the service efficiently, so $m \equiv N$. This is seen in Figure 1. Free entry implies that total revenue pN must be driven down to opportunity cost K in equilibrium. This equation, $pN = K$, is the rectangular hyperbola in Figure 1. It is competitive supply price. Market equilibrium occurs where demand intersects supply from above. Suppose the seller were to charge price p_1. Then the value of sales exceeds K and rents are nonzero. Therefore another seller would enter and charge a slightly lower price, attracting all business away from the initial seller. By continuation, price must be driven down in equilibrium to p^*, rents are driven to zero, there is one seller and potential entry maintains that situation indefinitely.

What happens when sellers have different talents? The demand function facing a more able seller is different from the one in Figure 1 because q is an argument of demand, $N(p,q)$. Whether N_q is positive or negative, less talented sellers are driven out of the

[9]The two functions $m(q)$ and $R(q)$ are the transforms from the distribution of ability to the distribution of output and reward. Inverting and computing the Jacobians, the distribution of output is $(1/v)\phi(m/v)$, the same form as the distribution of talent because $m(q)$ is linear. The distribution of rent is $(v(8R)^{1/2})\phi((2R/v)^{1/2})$, which is skewed to the right relative to ϕ.

narket. To see this, note that $R(q)=p\cdot N(p,q)$ in this case. Therefore

$$14)\quad R'(q)=N[1+(p/N)\partial N/\partial p]\partial p/\partial q+p(\partial N/\partial q).$$

Given the structure of demand above, equation (4) implies that $\partial p/\partial q=v$. Furthermore, t is easy to show that the price and quality elasticities of demand for quantities are related to the full price elasticity of services as follows:

$$(p/N)\partial N/\partial p=\theta(v/Y)\partial Y/\partial v,$$
$$(q/N)\partial N/\partial q=-[1+(v/Y)\partial Y/\partial v],$$

where $\theta=p/(p+s)$ is the share of full price accounted for by nonfixed costs and $Y=\Sigma y$ with the sum extending over individual consumers. The quality elasticity of demand for quantity is negative if the full price elasticity of demand for services is inelastic. Substituting these relations into (14) and simplifying yields

$$15)\quad R'(q)=Nv(1-\theta)>0.$$

Consider the following two cases:

(i) Assume $\phi(q)$ is dense on the interval $q_0,q]$, where q_0 is the least talented and q he most talented potential seller. Equation 15) shows that R is increasing in both q and). For a given value of v all sellers for whom $R(q)-K>0$ would choose to enter and, since $R'>0$, they must be selected from the upper ail of $\phi(q)$. But in equilibrium there is only one seller. Therefore v must adjust so that $R(\bar{q})-K=0$ and all people for whom $q<\bar{q}$ rationally choose the alternative occupation. There is no rent in equilibrium when ϕ is dense even though there is a single seller, because someone is waiting in the wings who is imperceptably different from that supplier.

(ii) Assume $\phi(q)$ basically the same as before, with the addition of outlier q^* a finite distance ε above $\bar{q}$: $q^*=\bar{q}+\varepsilon$. The Superstar is perceptably different from the closest rival and earns rent on this unique talent. Now it is q^* who supplies the service. Equilibrium v must be slightly smaller than in case (i) so that people for whom $q\leqslant\bar{q}$ choose not to compete. q^* charges price $p^*=vq^*-s$ (see equation (4), whereas $\bar{q}$ would charge $\bar{p}=v\bar{q}-s$. The price differential $p^*-p=v\varepsilon$ is the unit rent accruing to q^*. This is a small number if ε is small. Yet the total rent received by q^* is $Nv\varepsilon$, which can be very large if N is large. Though unit rent is limited by the equalizing difference (4) and the supply (distance) of close competitors, scale economies can make total rent very large in equilibrium.[10]

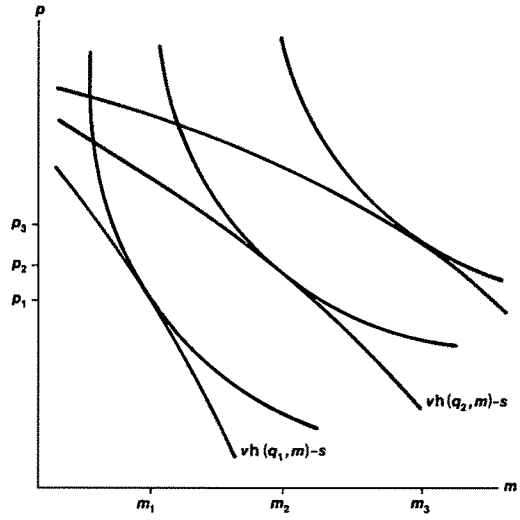

FIGURE 2

C. *External Diseconomies*

External diseconomies support a nondegenerate equilibrium distribution of sellers. The spatial structure of the market is illustrated in Figure 2. Given the market full price v, prices charged by sellers of different talent must satisfy (4) and $z=h(q,m)$. Therefore a seller of talent q must solve the following constrained maximum problem:

$$(16)\quad \max_m\,[pm-C(m)] \quad \text{subject to} \quad p=vh(q,m)-s.$$

[10]The equilibrium concept used in this particular example is the same as the notion of sustainability in natural monopoly. The equilibrium in Figure 1 is inefficient. This inefficiency vanishes when the externality is bounded sufficiently by either internal or external diseconomies. Those bounds are implicitly assumed in all other portions of this paper.

To examine the pure effect of externalities assume no internal diseconomies, $C(m)\equiv 0$. Two families of curves are shown in Figure 2, one corresponding to the objective function, and the other to the constraint at alternative values of q. A seller of given talent q_1 is constrained by both consumer preferences and sellers of other talents to charge prices along the curve marked $vh(q_1,m)-s$; seller q_2 is constrained by the presence of q_1 and others to operate along $vh(q_2 m)-s$, etc. The isorevenue curves are rectangular hyperbolas. Points of tangency between the two represent the solution to (9) and (10) or to (16) for each value of q. Thus q_1 charges price p_1 and has a market size m_1; q_2 charges p_2 and sells m_2 units, etc.

The importance of the crowding condition $h_{qm}>0$ is now apparent. Since the services produced by more talented sellers are less contaminated by crowding, the quantity-price gradient grows as talent increases. Therefore the better sellers can and do handle much larger crowds in equilibrium. Equation (11) demonstrates that the market size gradient increases with q when h_{qm} is positive. To see what effect this has on prices, differentiate the constraint in (16) with respect to q:

$$(17)\qquad dp/dq=vh_q+vh_m(\partial m/\partial q).$$

The first term is positive, but the second is negative if $\partial m/\partial q>0$, which it must be if $h_{qm}>0$. The extra crowding and dilution of unit service of high quality sellers constrains unit prices from rising with quality as much as they would without it. Figure 2 shows market size increasing with quality to a much larger extent than the price-quality gradient. It is definitely not irrational for better sellers to have a great deal of business, but prices that are not much higher than those with lesser talents. The market may impel them to act that way, to become relatively "crowded out" in equilibrium.

With only internal diseconomies, the multiplicative effect of both positive price and quantity gradients with respect to quality implies convexity of the return function $R(q)$. In this case the quantity gradient tends to be larger and the price gradient tends to be smaller. Nevertheless, there are strong forces working toward convexity. Substitute (11) into (13) to obtain

$$(18)\ R''(q)=-v^2(h_q+mh_{qm})^2 /(2vh_m+vmh_{qm}-C'')+vmh_{qq}$$

Since the first term in (18) is positive, $R(q)$ i convex so long as h_{qq} is not sufficientl negative. In fact, given the caveat abou $h_{qq}, R''(q)>0$ independent of the sign o h_{qm}. When $h_{qm}<0$ the constraint functions i Figure 2 become steeper as q increases, tend ing to stretch out the equilibrium price quality gradient and to compress the quan tity-quality gradient, just the opposite of th case where $h_{qm}>0$. Symmetry of the rewar function in p and m implies similarity o $R(q)$ in either case.

The effects of external diseconomies ar illustrated by the following example. Let $z=h(q,m)=q-a(q/m)^{-b}$ where a and b ar constants. Here adulteration depends on th talent-audience ratio and the unadulterate service satisfies $z=h(q,0)=q$. Assuming $s=0$, it is readily verified that $p(q)$ is propor tional to q, $m(q)$ to $q^{1+1/b}$ and $R(q)$ t $q^{2+1/b}$. Suppose $b=1$. Then p is linear in q m is quadratic in q, and R is a cubic in q. A seller that is twice as talented has a marke that is four times larger and earns eight time more money. If $b=1/2$ market size grow with the cube of talent and incomes b powers of four: a seller who is twice a talented earns sixteen times more, but onl charges prices that are twice as large.[11]

IV. Heterogeneous Consumers

Consumer differences in intensity of de mand for services are unrestricted in Sectio III, though much use is made of the assump tion that s is identical among them. How

[11] Notice that with imperfect information the effect o a reputation and fixed costs creates a type of scal economy which broadens the scope of this result. If tw scholars write on the same subject, the one with th better track record is much more likely to be read an subsequently cited. Similarly, a firm with a fine reputa tion is more likely to get the business than one that is o unknown quality. While a reputation has many of th elements of a public good, the analogy is not quit complete because this discussion ignores the dynamic of how reputations are established. An "epidemic model' is an intriguing possibility.

hould the equilibrium be described when s s distributed in the population of customers? That analysis is more complex because there s no longer a single equilibrium market price or services, v, that summarizes all the information. Nevertheless, differences in s imply estrictions on market outcomes that actually trengthen the qualitative results. I do not ttempt a full analysis here, but the reason is hat the market assignment of customers to ellers may force the relationship between p nd z to be convex. Therefore the more alented sellers receive even greater rents and ervice even larger markets than when p is inear in z as in (4).

That $p(z)$ must be convex can be sketched s follows: Figure 3 shows the equalizing lifference function (4) for two types of ustomers, s_1 and s_2, at alternative values of . Each line represents the willingness to pay or z at a given utility index. At the same value of v the functions are parallel and s_1 ype consumers outbid s_2 types at all values of z. In equilibrium the relevant v (the negative of the utility index) for type s_2 must exceed that for type s_1. Otherwise the former group would not purchase the service at all. Consequently the observed market relation must be the envelope of functions such as $p=v_1z-s_1$ and $p=v_2z-s_2$, the heavier curve in Figure 3. The envelope is convex. Evidently the main features of the analysis above hold for each linear piece of $p(z)$ in Figure 3. There are, however, additional implications of sorting between segments. First, the more talented sellers gravitate to that segment of the market with the largest value of v, precisely the reason why the convexity implications of the previous analysis are strengthened. Second, consumers with smaller values of s buy from less talented sellers. This is quantity-quality substitution at work: buyers with smaller values of s find quantity relatively cheaper and economize on quality, while those with large values of s demand greater quality and economize on quantity. Adding more types of consumers smooths the locus of equilibrium points in Figure 3 without affecting the general principles.[12]

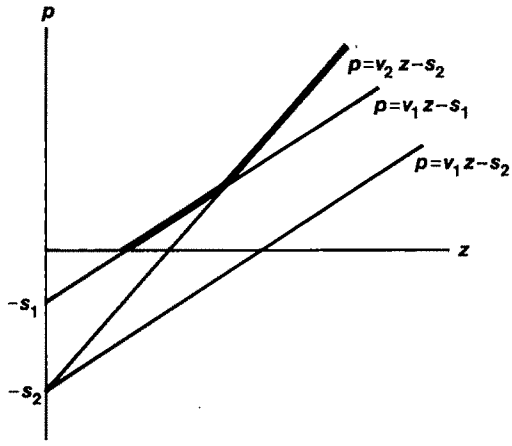

FIGURE 3

V. Comparative Statics

Since Section IV indicated that the qualitative results are not affected, it is convenient to exploit the assumption of common s in the consuming population. Demand and supply shifts are considered in turn.

A. *Demand Shifts*

An increase in the number of consumers or in the intensity of their demands for y increases the market demand for services. Market equilibrium price v rises due to rising supply price. Hence unit prices, $p(q)$, of all sellers increases. Since $R(q)$ increases everywhere, less talented people enter. At the same time, existing sellers expand their scales of operations. Though average quality of sellers falls, all previous entrants earn larger rents than before, and the largest increases accrue to the most talented persons (see the effect of v in equation (13) or (18)). Therefore the distribution of reward becomes more skewed than before.

The important practical implication is that it is monetarily advantageous to operate in a larger overall market; and it is increasingly advantageous the more talented one is. No

[12]Reder points out that the market is less concentrated if there are differences of opinion on who is the most talented. This raises subtle questions of the definition of markets that remain to be solved. An approximate solution in the analysis here is to adjust the density of $\phi(q)$: if several sellers are thought by different customers to have the same value of q, that is nearly the same as more mass in ϕ at that value.

wonder that the best economists tend to be theorists and methodologists rather than narrow field specialists, that the best artists sell their work in the great markets of New York and Paris, not Cincinnati, or that the best writers are connected with the primary literary centers such as New York or London. The best doctors, lawyers, and professional athletes should be found more frequently in larger cities. For a given place in the distribution of talent, it is more lucrative to be a violinist than an accordianist, a heavyweight than a flyweight, a rock musician than a folk singer, a tennis player than a bowler, or a writer of elementary texts rather than of monographs.

B. *Supply Shifts*

The interesting experiments are changes in internal and external diseconomies. Lesser diseconomies increase the market supply of services, reduce the equilibrium value of v, and make consumers better off. The effects on the distributions of talents and rents are less obvious and complicated by the presence of two opposing forces: the reduction in v lowers unit prices of all sellers, tending to decrease individual output and reward; whereas the reduction in costs or congestion tends to increase them. The balance between the two depends on the elasticity of demand for services.

If demand for services is sufficiently elastic, then cost reducing effects swamp the decline in unit prices and rents of sellers increase. The rent-talent gradient increases as well and there is greater concentration in the distribution of rewards among the most talented. A reduction in the internal diseconomy induces entry at the extensive margin, and the average seller becomes less talented. However, a reduction of the external diseconomy, if large enough, can actually reduce the number of sellers, kicking out the less talented and increasing the average quality of those remaining. If demand is inelastic, then the number of sellers declines and, since those leaving are selected from the lower tail, the average remaining talent rises. Effects on the return function $R(q)$ are ambiguous in this case, though sufficient reductions in the costs of congestion still can imply increases in both $R(q)$ and $R'(q)$. However that is a less likely outcome than when demand is elastic.

The practical importance of all this is related to technical changes that have increased the extent of scale economies over time in many activities. Motion pictures, radio, television, phono reproduction equipment, and other changes in communications have decreased the real price of entertainment services, but have also increased the scope of each performer's audience. The effect of radio and records on popular singers' incomes and the influence of television on the incomes of news reporters and professional athletes are good cases in point. And there are fine gradiations within these categories. Television is evidently a more effective medium for American football and basketball than it is for bowling, and incomes reflect it. Nonetheless, television has had an enormous impact on the incomes of the top bowlers, golfers, and tennis players because their markets have expanded. The "demise" of the theatre is more a complaint about competition from the larger scale media; and incomes of the top performers in the theatre, motion pictures, and television certainly are closely geared to audience size. These changes are not confined to the entertainment sector. Undoubtedly, secular changes in communications and transportation have expanded the potential market for all kinds of professional and information services, and allowed many of the top practitioners to operate at a national or even international scale. With elastic demands there is a tendency for increasing concentration of income at the top as well as greater rents for all sellers as these changes proceed over time.

C. *Interactions*

A change in s shifts the supply of services, not demand, even though it is a consumer parameter. This has no counterpart in standard theory. Demand is not directly affected because v embodies all relevant information for the consumption decision. Supply is shifted because s affects unit prices (see (4)). An increase in s reduces unit prices at any

value of v and reduces market supply. Therefore the equilibrium service price v increases and the rent distribution is altered in favor of the more talented sellers. The less talented leave the market. Both the increase in average quality of sellers and greater concentration in rewards at the top reflect customers' substitution of quality for quantity as s rises.

Since important components of s are time and effort costs, time-series changes are correlated with consumer earnings. Therefore market demand increases at the same time that supply is reduced, resulting in an even greater increase in v and additional skew. It can even push the extensive margin down rather than up. The incentives for investments in time saving innovations that tend to reduce s as earnings rise, for example, consumption at home, have been well remarked upon in the literature.[13]

VI. Conclusion

In discussing the general influence of economic progress on value, Alfred Marshall wrote:

> The relative fall in the incomes to be earned by moderate ability... is accentuated by the rise in those that are obtained by many men of extraordinary ability. There never was a time at which moderately good oil paintings sold more cheaply than now, and ... at which first-rate paintings sold so dearly. A business man of average ability and average good fortune gets now a lower rate of profits... than at any previous time, while the operations, in which a man exceptionally favoured by genius and good luck can take part, are so extensive as to enable him to amass a large fortune with a rapidity hitherto unknown.
>
> The causes of this change are two; firstly, the general growth of wealth, and secondly, the development of new facilities for communication by which men, who have once attained a commanding position, are enabled to apply their constructive or speculative genius to undertakings vaster, and extending over a wider area, than ever before.
>
> It is the first cause... that enables some barristers to command very high fees, for a rich client whose reputation, or fortune, or both, are at stake will scarcely count any price too high to secure the services of the best man he can get: and it is this again that enables jockeys and painters and musicians of exceptional ability to get very high prices... . But so long as the number of persons who can be reached by a human voice is strictly limited, it is not very likely that any singer will make an advance on the £10,000 said to have been earned in a season by Mrs. Billington at the beginning of the last century, nearly as great as that which the business leaders of the present generation have made on those of the last. [pp.685–86]

Even adjusted for 1981 prices, Mrs. Billington must be a pale shadow beside Pavarotti.[14] Imagine her income had radio and phonograph records existed in 1801! What changes in the future will be wrought by cable, video cassettes, and home computers?

[13]See Becker (1965).

[14]The entries for Elizabeth Billington in the eleventh edition of the *Encyclopedia Britannica* and *Grove's Musical Dictionary* indicate that she earned somewhere between £10,000 and £15,000 in the 1801 season singing Italian Opera in Covent Garden and Drury Lane. She is reported to have had an extraordinary voice and was highly paid throughout her professional life, but there is a hint that the 1801 sum was unusual even for her. No information is given on endorsements.

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A Loanable Funds Theory of Unemployment and Monetary Disequilibrium

By MEIR KOHN*

In an important recent paper, Axel Leijonhufvud lays the blame for the ills of modern macroeconomics not on Keynes' interpreters, as he has in the past, but on the *General Theory* itself. He sees the *General Theory* both as a refinement of Wicksellian monetary theory and as a departure from it—the refinement being the income-expenditure analysis; the departure the liquidity-preference theory of interest. That departure, Leijonhufvud believes, is the root of most of the problems of modern macroeconomics. To undo the damage, he argues, we must abandon our current macroeconomics in favor of one that combines Keynes' income-expenditure analysis with the theory of interest Keynes rejected—the loanable funds theory. The purpose of this paper is to follow Leijonhufvud's advice and to develop just such a synthesis.

Perhaps the clearest exposition of Wicksellian monetary theory is that of Dennis Robertson (1934). It goes something like this: The market for loanable funds is described by a demand curve "representing the declining marginal productivity of new lendings in industrial use," and by a supply curve "representing the rate of new available savings per atom of time—available that is after deducting new savings absorbed in financing consumption by governments or individuals." The demand curve, *DD*, and the supply curve, *SS*, for a fully employed economy are shown in Figure 1. The rate of interest at which supply equals demand is called *the natural rate*.[1]

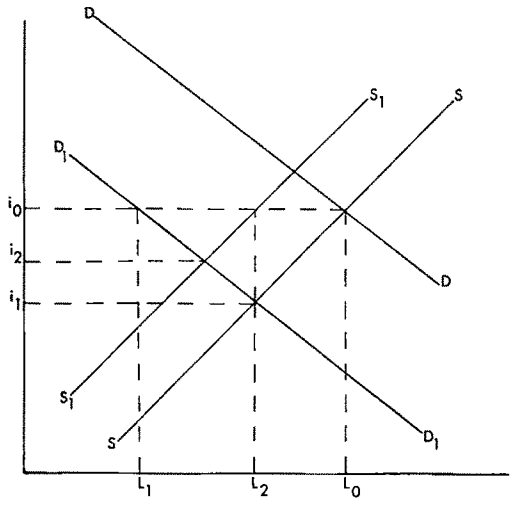

FIGURE 1. THE MARKET FOR LOANABLE FUNDS

Suppose there is an exogenous fall in the "marginal efficiency of capital" causing the demand curve to fall to D_1D_1 and the natural rate to i_1. Suppose, too, that the market rate of interest is prevented from falling to the new natural rate by someone willing to satisfy the excess demand for securities at the original natural rate of i_0. (In the *Treatise* the "someone" is the community of bear speculators; in Wicksell it is commercial banks.) This intervention implies a "leakage" of funds out of the circular flow and into the hands of the intervening agent. The leakage results in a deflationary pressure on the economy, causing income to fall through either a fall in prices, a fall in employment, or a fall in both. The fall in income causes

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[1]Robertson added:

It would be misleading to say that the rate of interest 'depends on' the intersection of these two curves, since there would be a rate of interest in a society in which no new capital was being formed, indeed even in a society in which capital was not productive and all borrowing was for consumption: nevertheless, in equilibrium the rate of interest [at which the two curves intersect] is the rate at which the new lendings which can be absorbed by industry per atom of time and the new available savings per atom of time are equal. At this rate (i.e., at one of the family of rates typified by [the rate at which the curves intersect]) the banks are continually renewing loans. [p. 85]

the supply schedule to shift leftwards to S_1S_1: net available savings are lower at any given rate of interest. Given the fall in income, the market-clearing rate of interest is now i_2 which Robertson calls the *quasi-natural* rate. The excess supply of funds at the supported rate, i_0, is reduced from $L_0 - L_1$ to $L_2 - L_1$.

The *General Theory* represented a major improvement over this Wicksellian analysis, Leijonhufvud suggests, in its explicit analysis of the feedback mechanism shifting the supply curve of loanable funds to the left—the income-expenditure theory—and in its demonstration that the quasi-natural rate could be pushed up all the way back to i_0, resulting in an "unemployment equilibrium." With the quasi-natural rate at i_0, there would no longer be any excess supply of loanable funds: the market rate of interest would stay where it was *with no further support necessary*. The only remaining disequilibrium would be in the labor market. The resulting unrelenting pressure on the money wage would be "unfair"—the price that was "wrong" being the interest rate, not the money wage—as well as ineffective in restoring the economy to full employment. So long as the interest rate remained above its natural level, the unemployment rate would remain above *its* natural level.

Leijonhufvud claims that this positive contribution was largely offset by a negative one in the form of Keynes' liquidity preference theory of interest. He suggests that Keynes was forced to find a new mechanism to determine the rate of interest, because, by defining saving as identically equal to investment, Keynes had destroyed the basis for the loanable funds theory: if saving and investment are identical, the rate of interest cannot be determined by their equality.[2] Keynes' "bootstrap" theory of interest wiped out th notion of a natural rate determined by pro ductivity and thrift.[3] It also obscured th crucial role played by maladjustment of th market rate in the emergence of persisten unemployment, the maladjustment being th result of divergent beliefs between en trepreneurs and speculators about intertem poral prospects. Leijonhufvud sees Keynes new theory of interest as a major error, on that has led to endless confusion and futil argument ever since.[4]

If we are to follow Leijonhufvud's sugges tion and reinstate the loanable funds theory the main problem is to decide just how i should differ from the liquidity-preferenc theory. However much they disagreed wit one another, all the protagonists in th lengthy loanable funds/liquidity-preferenc controversy—with the sole exception o Keynes himself—were united in maintainin that the two theories, if specified correctly must arrive at the same conclusions. Sectio I argues that the essential difference betwee the two theories lies not in the choice o "which market to eliminate," but in th choice of analytical method. A loanable fund model is proposed that incorporates th Keynesian income-expenditure mechanism i a Robertsonian sequence analysis. The resulting loanable funds model applies to a much shorter "run" than *ISLM*, the relatio between the two being like that betwee Marshall's market day and his short run. This much shorter run facilitates the analysis of impact effects, and in Section II the model is used to analyze the impact effects of changes in the marginal efficiency of capital

[2]This is not quite fair to Keynes. Compare:

Aggregate saving and aggregate investment, in the senses in which I have defined them, are necessarily equal in the same way in which the aggregate purchases of anything on the market are equal to the aggregate sales. But this does not mean that 'buying' and 'selling' are identical terms, and that the laws of supply and demand are meaningless... [The] novelty lies in my maintaining that it is not the rate of interest, but the level of incomes which ensures equality between savings and investment. The arguments which lead up to this initial conclusion are independent of my subsequent theory of the rate of interest, and in fact I reached it before I had reached the latter theory. But the result of it was to leave the rate of interest in the air. If the rate of interest is not determined by saving and investment in the same way in which price is determined by supply and demand, how is it determined? [1937, pp. 211–12]

[3]In the context of *ISLM*, only in the "extreme Keynesian case" of a horizontal *LM* curve is the rate of interest *purely* a bootstrap (monetary) variable. On the other hand, only in the "extreme monetarist case" of a horizontal *IS* curve does the monetary element disappear entirely.

[4]G. L. S. Shackle, too, has taken Keynes to task on this point. See Shackle, pp. 11–13 and p. 53.

and in the marginal propensity to consume. In Section III an equilibrium over time of the loanable funds model is defined and used to analyze the effects of the same changes in the "short run"—the run of *ISLM*. Section IV discusses the results and their implications for some of Leijonhufvud's propositions. It is found that the loanable funds theory supports the existence of an unemployment equilibrium if and only if the money wage is completely rigid. It is also found that if unemployment equilibrium *is* possible, the rate of interest is indeterminate, so that a bootstrap theory of interest becomes a necessity. Keynes' "Paradox of Thrift" is considered. The loanable funds model is compared to *ISLM*, and the latter is found to be a special case of the former.

I. The Model

It is quite wrong, as we shall see, to characterize the difference between the loanable funds and liquidity-preference theories of interest in terms of "which market is left out." As Harry Johnson observed, the basic difference lies, rather, in the choice of analytical method:

> The Robertsonian theory is a dynamic theory: it deals with the equilibrium reached in a short interval of time... and by taking a succession of such short periods, each of which creates the conditions which are taken as fixed in the next period, it traces out the path of various economic magnitudes over time. The equilibrium reached during a particular period only represents an equilibrium of *all* the forces at work if all economic magnitudes are the same at the end of the period as at the beginning....
>
> The Keynesian theory on the other hand, is a static theory; it is not concerned with the succession of changing equilibrium positions but only with the position which represents an equilibrium of all forces at work. [p. 91]

The economic meaning of the unit period in the Robertsonian theory is of great importance. The period is one "during which... the stock of money changes hands once in final exchange for the constituents of the community's real income or output" (1933, p. 65). Hence, "a man's disposable income—the income about which the question arises... as to whether it shall be 'saved' or 'spent'—is... the income received not [in that period] but in the previous one." The individual therefore faces a *finance constraint*: during a given period he may dispose only of the money he possesses at the outset of that period. The underlying paradigm—common to all theories in the Wicksellian tradition, including Keynes' own *Treatise*—is the circular flow of money payments. The flow is carefully traced out, this period's payments making up next period's income.[5]

In contrast, the Keynesian theory represents an attempt to characterize directly the "ultimate" equilibrium in which all of the forces making for period-by-period change have worked themselves out. The flow of money payments is not traced explicitly. It is assumed—implicity, as in Patinkin, or explicitly, as in Radcliffe—that once individuals have decided on a mutually consistent set of real transactions, the monetary arrangements will somehow sort themselves out.[6] The precise relationship between the two types of theory will become clearer as the analysis procedes.

The following model formalizes the Robertsonian sequence analysis and incorporates into it the Keynesian income-expenditure mechanism. The economy consists of three types of agents—firms, households, and bank/speculators. The general structure of the model is illustrated in the circular flow diagram of Figure 2.

[5]The use of finance constraints to express algebraically the idea of a circular flow of money payments has appeared more recently in S. C. Tsiang (1966, 1980) and in Victoria Chick.

[6]There is no reason why neglecting the flow of money payments *has* to lead to trouble. Indeed, we will see below that there are circumstances in which the Robertsonian and the Keynesian theories lead to identical results. However, such neglect may lead to inconsistencies: examples are given by Robert Clower (1967) in his critique of Don Patinkin. Concern with possible problems of this sort underlies the literature on the "government budget constraint" (see, for example, Carl Christ).

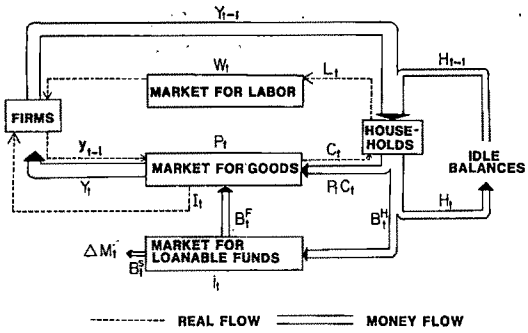

FIGURE 2. THE CIRCULAR FLOW OF MONEY PAYMENTS

A. *Firms*

Firms face an aggregate production function

$$(1) \qquad y_t = F(L_t),\ F'>0,\ F''<0,$$

where y is aggregate output of the composite good and L is employment. They plan production to maximize profits. Assuming the production period to be the same length as the period of analysis, profit maximization requires that

$$(2) \qquad P^e_{t+1}F'(L_t) = W_t,$$

where P^e_{t+1} is the price level expected in the next period when output is sold and W_t is the contractual money wage paid at the end of the current period (the beginning of the next).[7]

Firms invest according to an investment function or "marginal efficiency of capital" schedule

$$(3) \qquad I_t = I(r_t, \theta),\ I_1<0,\ I_2>0,$$

where I_t is real investment, r_t is the real rate of interest, and θ represents "long-run expectations." The real rate of interest is

$$(4) \qquad r_t \equiv (1+i_t)/(1+\rho^e_t) - 1,$$

where ρ^e_t is the unanimously expected rate of change of the price level. In the "run" of the analysis, investment does not affect the production function.

At the end of any period, firms hold the money proceeds of that period's sales

$$(5) \qquad Y_t \equiv P_t y_{t-1}.$$

This sum is all paid out to households either as wages (a total of W_tL_t) or as "profits" (interest and dividend payments). Earnings are not retained, precluding the internal financing of investment.[8] Firms must finance all their investment by issuing new securities. The supply of new securities (the demand for loanable funds), B^F_t, is therefore

$$(6) \qquad B^F_t \equiv P_t I_t.$$

B. *Households*

Households supply labor and finance to firms and receive labor and nonlabor income at the end of each period. The aggregate supply of labor is a function of the expected real wage, w:

$$(7) \qquad L^s_t = L^s(w_t),\ L^{s\prime} \geqslant 0.$$

The money wage for period t is set at the beginning of period t, but received at the end of the period, so that it is available to be spent in period $(t+1)$. Hence, the expected real wage is the contractual money wage, W_t, divided by the price level expected in period $(t+1)$, P^e_{t+1}.

At the beginning of a period, households hold all the money then in circulation, M_t. Some has just been received as money income, Y_{t-1}, and the rest carried over from the previous period unspent as "idle balances," H_{t-1}. That is,

$$(8) \qquad M_t \equiv Y_{t-1} + H_{t-1}.$$

In terms of the circular flow, Y_{t-1} is the inflow of money, and H_{t-1} the contents of

[7]Strictly speaking, the profit-maximization condition should be $P^e_{t+1}F'(L_t) = (1+i_t)W_t$ because wages are paid one period before profits are received. The analysis is considerably simplified if this interest charge is ignored, and none of the major results are affected. Where it makes any difference this will be noted. See my 1981b paper for an elaboration and for an analysis which recognizes the interest charge.

[8]Assuming that firms do not retain earnings greatly simplifies the analysis. The relevance of the assumption for the finance constraint is considered in my 1981a article. It has no bearing on the conclusions of this paper.

the "money reservoir." Since there will be no new inflow until the beginning of the next period, outflows during the current period cannot exceed M_t. This conservation principle may be expressed in the form of a finance constraint

$$(9) \qquad M_t \geq P_t C_t + B_t^H,$$

where C_t is real consumption, $P_t C_t$ is the money value of consumption, and B_t^H is the money value of household acquisitions of securities.

Households as a group are assumed to be a surplus sector—net lenders to firms. This does not mean that individual households cannot be deficit units. Indeed, the possibilities of borrowing and lending and of trade in existing assets among households imply that the finance constraint faced by an individual household is less strict than (9). However, on aggregation, the interhousehold transactions net out, and the strict aggregate finance constraint remains in force.[9]

The "slack" of the finance constraint is made up of idle balances held over to the next period, so that

$$(10) \qquad M_t \equiv P_t C_t + B_t^H + H_t.$$

However the representative household sets C_t, B_t^H, and M_t^I, that decision must be consistent with identity (10). There are only two degrees of freedom in deciding the three variables: the value of the third variable is imposed by (10).

The essence of Keynes' income-expenditure theory is that consumption expenditure will increase with income, but not by as much. This may be expressed by the following consumption function:

$$(11) \qquad C_t = \beta Y_{t-1}/P_t, \; 0<\beta<1.$$

The relevant income variable—"the income about which the question arises... whether it shall be 'saved' or 'spent'"—is disposable real income—last period's money income divided by this period's price.[10] Although, in principle, the propensity to consume may depend on income expectations, asset values, and asset yields, this possibility will be ignored here, as it is in the simple Keynesian model.

Money not spent on consumption may either be lent to firms or held over to the next period as idle balances. Only one of the two functions determining the supply of loanable funds and the demand for idle balances may be specified independently: the other will be defined implicitly by the one specified, together with the consumption function and identity (10). Of the two, it will prove more convenient to specify the demand for idle balances. This is assumed to be a nondecreasing function of planned expenditure, reflecting the value of idle balances in easing money management and their value as a precautionary reserve.[11] The demand for idle balances is also assumed to be a decreasing function of their opportunity cost—the nominal rate of interest. Hence,

$$(12) \quad H_t = H(P_t C_t, i_t), \; H_1 \geq 0, \; H_2 < 0.$$

H is assumed not to depend on asset stocks and to be homogeneous of degree one in planned expenditure. The implicitly defined supply function of loanable funds is

$$(13) \quad B_t^H \equiv M_t - P_t C_t - H(P_t C_t, i_t):$$

the supply of loanable funds is a declining function of planned consumption expenditure and an increasing function of the nominal rate of interest.[12]

[9]See my 1981a article for a more detailed discussion.

[10]Strictly speaking, real money income should be corrected for capital gains or losses on idle balances (as is done in my 1981b paper). This correction is ignored here as it would complicate the analysis without affecting any of the conclusions.

[11]As Lucas explains, there need be no inconsistency between a nonstochastic aggregate planned expenditure and individual uncertainty about spending plans. Hence, the existence of precautionary balances does not logically necessitate a stochastic aggregate model.

[12]The yield on securities is a reward *both* for "not-hoarding" and for "not-spending." Compare Robertson's criticism of the liquidity preference doctrine:

> A small boy at school is told that if he wins a race he may have either an apple or an orange: he wins the race and chooses the orange. When his mother asks him how he got it, must he reply, 'I got it for not eating an apple'? May he not say proudly 'I got it for not losing a race'? [1940, pp. 16–17]

C. *Bank/Speculators*

In addition to firms and households, there is a third type of agent active in the market for loanable funds—the bank/speculator. The institutional form of this agent may differ, as is explained below, but its economic role will be the same—to stabilize the rate of interest. Although this stabilization will prove to be the source of considerable mischief, this mischief is an almost inevitable consequence of an essentially useful economic function. In general, the bank/speculator will act to reduce the volatility of the market rate of interest in the face of nonsystematic, transient movements of the supply and demand for loanable funds. The bank/speculator may also, occasionally, resist a change that is both systematic and permanent. We will see that such interference with a necessary adjustment may cause considerable disruption. It should be realized, however, that the problem facing the bank/speculator in distinguishing between transient and permanent changes—the former to be resisted and the latter not—is far from trivial. In terms of the market information observed by the bank/speculator, there will be no difference, at least initially, between the two types of disturbance. Identification will be a matter of judgement, and judgement is fallible.

The role of bank/speculator may be played by any of the following:

1. *Wicksellian Banks.* All new borrowing and lending is intermediated by commercial banks. Individuals buy indirect securities (time deposits), and banks buy new securities from firms (make loans). The market rate of interest is set by banks. If the market rate is set too high, time deposits will accumulate faster than loans, and the amount of demand deposits—the quantity of money in circulation—will fall.[13] The effect of a market rate set too low is quite symmetric. It is usual, but not necessary, to assume all money to be "inside money" created by banks. It will be assumed that all bank income goes back to households either as yields on time deposits or as bank profits.[14] Thus, the actions of the bank in setting the market rate of interest will have no direct effect on disposable income. It will, of course, have an indirect effect as we shall see.

2. *A Central Bank.* There exists a central bank with a large stock of securities and the power to print money. It may peg the market rate of interest by standing ready to buy or sell securities at that rate. The securities held by the central bank have been issued by firms and the income on these securities is returned to households in some way, so that open market operations have no direct effect on disposable income. In the pure case, there are no private banks, and therefore no multiple expansion of deposits.

3. *Keynesian Speculators.* There exists a class of individuals who speculate on the price of securities. If they expect the price of securities to fall (the market rate of interest to rise), they sell; if they expect the price of securities to rise, they buy. The stock of securities they hold is large enough to satisfy households' demand for additional securities for a considerable time, thus preventing the market rate of interest from falling. It is assumed that speculators dispose of their income just like households, so that the movement of securities from the portfolios of speculators to the portfolios of ordinary households has no direct effect on the relation between expenditure and income. If speculators prevent the rate of interest from falling, they will find their cash balances increasing. These "speculative" balances (held against an expected fall in security prices) are effectively removed from circulation, with the same deflationary effect as that achieved in similar circumstances by the Wicksellian banks or by the central bank. This embodiment of speculative behavior in a separate economic agent differs from the usual Keynesian practice of including it as a part of normal household behavior. Such a

[13]Suppose households save $100 of money income by transferring it from their demand deposits to new time deposits. The quantity of money in circulation will fall by $100 unless the bank makes new loans to firms of the same amount.

[14]The source of bank income is "profits"—nonlabor income—from firms. Some of this flows to households via banks.

eparation has two expositional advantages. 'irst, it emphasizes the essential similarity etween the role of Keynesian speculators nd the role of the other two agents who may nterfere with the "correct" functioning of he loanable funds market. Second, it sugests that such large scale interference by peculators is not a normal occurrence.

In the sequel we will not need to choose etween the three alternative characterizaions. Indeed, any combination would serve qually well. All that matters for our argunent is that someone, the bank/speculator, ntervenes in the loanable funds market to revent the market rate of interest from fallng. As a result, money is removed from irculation. The change in the amount of noney in circulation is

$$(14) \qquad \Delta M_t \equiv (M_{t+1} - M_t) \equiv -B_t^S,$$

where B_t^S is the supply of securities by the bank/speculator. For this definition to cover all three cases, we must exclude from our definition of M_t the speculative balances held by Keynesian speculators.

II. The Single Period Solution

The single period solution may be compared to the Hicksian "temporary equilibrium" from which it differs principally in the definition of the unit period. In the loanable funds model the unit period is the length of time between successive payments of money income, the period of time over which the finance constraint is effective.[15] It also represents, for simplicity, the production period, although there is no reason in principle for the two periods to coincide. We will first examine the conditions for a single period equilibrium, and then go on to consider the impact effect of an exogenous change.

A. Conditions for A Solution

1. *The Market for Goods.* The quantity of the composite good offered for sale is the quantity produced in the *preceding* period. No inventories are held, so that the supply is completely inelastic in the current period. The market for goods always clears.[16] For this to happen, the quantity offered for sale must equal the sum of the quantities demanded for consumption (from (11)) and for investment (from (3)). That is,

$$(15) \qquad y_{t-1} = \beta Y_{t-1}/P_t + I(r_t, \theta).$$

Real aggregate demand, the right-hand side of (15), is an increasing function of disposable money income, a decreasing function of current prices and of the real rate of interest, and homogeneous of degree zero in money income and current prices.

2. *The Market for Labor.* This market will clear when the following condition, derived from (2) and (7), is satisfied:

$$(16) \qquad F'\big(L^S(w_t)\big) = w_t.$$

Note that the real wage is an "expected" variable: $w_t \equiv W_t/P_{t+1}^e$, where W_t is the contractual money wage, and P_{t+1}^e is the price of the composite good expected by both firms and households in the next period. An equilibrium real wage is assumed always to exist.

If the equilibrium real wage does not obtain, the labor market will not clear.[17] In particular, adjustment of the real wage may be hindered by "stickiness" of the money wage: although the money wage does react to excess supply in the market for labor, it may not react quickly enough to clear the market within a single period. Such an imperfect adjustment might be represented by

$$(17) \qquad W_t - W_{t-1} = \alpha(W_t^* - W_{t-1}),$$

[15]In the model all income payments are synchronized. It would be possible to construct a more complicated model in which income payments would not be synchronized and in which the length of the period would represent the *average* income period. My 1981a article shows that in such a model the aggregate finance constraint is still in force.

[16]Richard Jackman argues strongly that these are precisely the assumptions about the goods market made in the *General Theory*.

[17]Another possible source of difficulty, the divergence of price expectations between firms and workers, is assumed not to exist.

where W_t^* satisfies (16) for a given P_{t+1}^e, and α is the "speed of adjustment." If α is zero, the money wage is completely rigid and no adjustment takes place; if α is unity, the money wage adjusts completely within a single period.

3. *The Market for Loanable Funds.* If the bank/speculator does not intervene, the market for loanable funds will clear if the supply of funds by households, B_t^H, equals the demand for funds by firms, B_t^F. Using (3), (6), (11), and (13), this condition may be written

$$(18)\quad P_t I(r_t, \theta) = M_t - \beta Y_{t-1} - H(\beta Y_{t-1}, i_t).$$

If the bank/speculator does intervene, then B_t^S must be taken into account, and, using (14), (18) becomes

$$(19)\quad P_t I(r_t, \theta) - \Delta M_t = M_t - \beta Y_{t-1} - H(\beta Y_{t-1}, i_t).$$

The effect of this intervention will be to stabilize the market rate of interest. It simplifies the analysis to assume that this stabilization is complete, so that the interest rate is pegged at a given level. That is,

$$(20)\quad i_t = \bar{i}.$$

4. *Interdependence and the "Market for Money."* We may combine the condition for clearing the market for goods, (15), with the condition for clearing the market for loanable funds, (18), to obtain

$$(21)\quad M_t = P_t y_{t-1} + H(\beta Y_{t-1}, i_t).$$

Satisfaction of condition (21) implies that the planned uses of money in expenditure, both consumption and investment, and in idle balances just exhaust the amount of money available to be used. Equation (21) could be called the condition for "clearing the market for money," although this terminology is obviously metaphorical. If the bank/speculator intervenes in the loanable funds market, then (19) must be used rather than (18), giving a modified condition for equilibrium in the uses of money:

$$(22)\quad M_t + \Delta M_t = P_t y_{t-1} + H(\beta Y_{t-1}, i_t).$$

There is an obvious interdependence be tween the condition for clearing the marke for goods, the condition for clearing th market for loanable funds, and the conditio for equilibrium in the uses of money: satis faction of any two of the conditions implie satisfaction of the third. The interdepen dence derives from the finance constraint on firms, (6), and on households, (10), a may be seen from Figure 2. This interdepen dence, an example of what Clower an Leijonhufvud call Say's Principle, is not quit the same as Walras' Law: notice that th equilibrium condition for the labor market i not involved in the interdependence. Th equilibrium condition for the labor market i excluded because it does not imply the *cur rent* payment of money and so does no impinge on the current finance constraints Current wages will be paid out of sales re ceipts expected to accrue by the end of th period, while last period's wages have al ready been paid.[18] This separation of th equilibrium condition for the market fo labor parallels the "dual decision hypothesis" in Clower (1965). The interdependence between the three other conditions makes it immaterial whether it is the condition fo equilibrium in the loanable funds market o the condition for equilibrium in the market for money that is left out when solving the system.

5. *The Single Period Solution.* Take expectations (ρ_t^e and P_{t+1}^e) as given. In period t, the values of y_{t-1}, Y_{t-1}, and M_t are predetermined. If both the money wage and the market rate of interest are free to adjust, then P_t, i_t, W_t, current output, the level of employment, and the allocation of y_{t-1} between consumption and investment will all be determined by equation (16) and any two of equations (15), (18), and (21). It is assumed that a solution exists. If expectations depend on current values of variables, solution of the system will be more complicated,

[18]It is assumed in the following that firms are always able to meet their payrolls. In the deflationary situations we will consider, with shrinking dollar payrolls, that is not an unreasonable assumption. There could, in principle, be difficulties, forcing firms to borrow to meet their payrolls.

but nothing in principle is changed. If the money wage is sticky, the labor market equilibrium condition must be modified accordingly. If the bank/speculator pegs the market rate of interest, (18) must be replaced by (19) and (20), (21) by (22), and i_t must be replaced by ΔM_t as an endogenous variable. If we specify an expectations mechanism generating ρ_t^e and P_{t+1}^e, then not only the current solution, but also the evolution of the system over time, is completely determined.

B. *The Impact Effect of an Exogenous Change*

Assume that prior to the exogenous disturbance the economy is in stationary equilibrium over time: both real and nominal magnitudes are constant and expectations are fulfilled. Following the disturbance, the dynamic behavior of the system will depend, for one thing, on the way that expectations adjust. It is assumed that for the first two periods after the change (the length of time considered), price level expectations are relatively inelastic and inflation expectations are completely inelastic, so that

$$\rho_1^e = 0. \tag{23}$$

Let us consider two types of response. In the first, the bank/speculator is neutral and allows the market rate of interest to adjust. In the second, the bank/speculator intervenes to stabilize the market rate of interest.

1. *No Intervention by the Bank/Speculator.* The price level P_1 and the interest rate i_1 are determined by the two conditions (15) and (21) (any two of (15), (18), and (21) would do) which may be written

$$Y_0 = \beta Y_0 / P_1 + I(i_1, \theta) \tag{24}$$

and

$$M_0 = P_1 y_0 + H(\beta Y_0, i_1). \tag{25}$$

(Note that, by (4) and (23), i_1 may be substituted for r_1 in (24).) The combinations of P_1 and i_1 satisfying (24), the market-clearing condition for the market for goods, are shown as the curve G_0G_0 in Figure 3. The combinations satisfying (25), the condition for equilibrium in the uses of money, are shown as the curve M_0M_0. In the absence of any exogenous change, the curves intersect at (P_0, i_0).

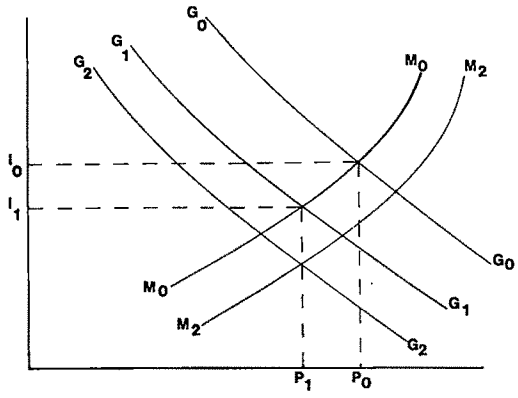

FIGURE 3. THE SINGLE PERIOD SOLUTION WITH NO INTERVENTION

Consider a fall in the marginal efficiency of capital caused by a fall in θ (long-run expectations). This shifts the GG curve down to G_1G_1 with no change in the MM curve. The rate of interest falls to i_1 and the price level to P_1. Investment falls and consumption rises. Disposable income in the *next* period, $Y_1 = P_1 y_0$, will fall, causing a fall in planned consumption, and thus a further downward shift of the GG curve to G_2G_2—the multiplier effect. Because of the dependence of idle balances on planned consumption, the MM curve will also fall to M_2M_2, exacerbating the fall in the rate of interest and moderating the fall in the price level. The effect on employment and output will depend on money wage flexibility and on the sensitivity of price expectations. If P_2^e falls more than W_1, the real wage will rise and there will be unemployment and a fall in output. The fall in output will tend to moderate the fall in prices in period 2.

By similar reasoning, a fall in the marginal propensity to consume can be shown to lead to an immediate fall in the rate of interest. The effect on the price level and on nominal income is uncertain because the MM curve falls as the reduced marginal propensity to consume reduces the demand for idle balances.

These results are consistent with those of a similar analysis by Tsian (1966). A change in either the marginal efficiency of capital or in the marginal propensity to consume, with the quantity of money fixed, will have an *immediate* impact on the rate of interest. This will happen *before* there is any multiplier effect on income with its resulting indirect feedback effect on the rate of interest. The immediate effect is totally absent in the *General Theory* and in *ISLM*; only the indirect effect is recognized.

2. *The Interest Rate Stabilized by the Bank/Speculator.* The conditions for clearing the markets for goods and for equilibrium in the uses of money are now

$$y_0 = \beta Y_0 / P_1 + I(\bar{i}, \theta) \tag{26}$$

and

$$M_0 + \Delta M_0 = P_1 y_0 + H(\beta Y_0, \bar{i}). \tag{27}$$

Notice that (21) is replaced by (22) as the basis of the equilibrium condition for the uses of money and that the rate of interest is replaced as an endogenous variable by ΔM_0. The bank/speculator pegs the interest rate by supplying securities completely elastically at that rate and by removing the quantity of money ΔM_0 from circulation. In this case, the impact of a fall in θ is entirely on the price level. From (26) it is clear that the price level must fall, and from (27) that this fall implies a negative ΔM_0. In the next period there will be a multiplier effect—Y_1 will be smaller than Y_0. The impact effect of a fall in the marginal propensity to consume is quite similar. The response of employment and output will again depend on the elasticity of price expectations and on the flexibility of the money wage.

III. The Short-Run Solution

Rather than working through the period-by-period adjustment of the model as the multiplier works itself out and as expectations adjust, we can solve directly for the new position of rest. Such a position—which I will call a short-run solution—will be either a stationary state, with both real and nominal magnitudes constant, or a steady state in which real magnitudes are constant and nominal magnitudes are changing at an equal and constant rate. In either case, expectations are fulfilled.[19] If prices are changing at a constant rate, then

$$P^e_{t+1} = (1+\rho) P_t, \tag{28}$$

and

$$\rho^e_t = \rho. \tag{29}$$

This short run is precisely the "run" of the *General Theory* and of *ISLM*.[20] The run is described as short because investment has no effect on output, because the accumulation of securities has no effect on households' demand for more securities, and because long-run expectations (θ in the marginal efficiency of capital schedule) are constant.

Our analysis will be comparative static: we will compare the short-run solution after an exogenous change with the short-run solution before the change. However, in contrast with *ISLM* analysis, we do have available to us the detailed dynamics taking us from one short-run solution to another. This is precisely the single period analysis of Section II.[21] If that dynamics is stable, the model

[19] "Perfect information" obtains because nothing is changing. Joan Robinson once suggested that this be called a state of perfect tranquillity rather than one of perfect information.

[20] Compare John Hicks:

> [A fundamental difference between Keynes' model and the model of *Value and Capital*] concerns the length of the period. Keynes' (he said) was a 'short-period,' a term with connotations derived from Marshall; we shall not go far wrong if we think of it as a year. Mine was an 'ultra-short-period'; I called it a week. Much more can happen in a year than in a week; Keynes has to allow for quite a lot of things to happen. [p. 141]

On the fulfillment of expectations, compare Keynes:

> I now feel that if I were writing the book again I should begin by setting forth my theory on the assumption that short period expectations were always fulfilled... For other economists, I find, lay the whole emphasis, and find the whole explanation in the *differences* between effective demand and income; and they are so convinced that this is the right course that they do not notice that in my treatment this is *not* so. [1973, p. 181]

[21] Attempts to "dynamize" *ISLM*—to bridge the gap between comparative static solutions—have been generally unsuccessful. While it is fairly simple to reduce a

will approach the short-run solution, directly or with oscillations, as the limit of the period-by-period adjustment. The dynamics will not, however, be considered explicitly in the current section.

We will examine the behavior of the model under various combinations of assumptions about money wage flexibility and interest rate stabilization.

A. *The "Classical" Case: Interest Rate and Money Wage Both Perfectly Flexible*

The short-run solution may be derived from three conditions—the respective conditions for clearing the labor market, for clearing the goods market, and for equilibrium in the uses of money:

$$F'(L^s(w))=w, \tag{30a}$$

$$F(L^s(w))=y, \tag{30b}$$

$$y=\beta y+I(i,\theta), \tag{31}$$

$$M=Py+H(\beta Py,i). \tag{32}$$

The time subscripts have been dropped since the solution is stationary: no variable real or nominal is changing. Note that this implies that real and nominal rates of interest are equal.

The three equations may be solved recursively. The condition for equilibrium in the labor market determines the real wage, employment (which is "full"), and—via the production function—output.[22] Given equilibrium output, the condition for equilibrium in the goods market determines the interest rate and the division of output between consumption and investment. Given output, the interest rate, and consumption, the condition for equilibrium in the uses of money determines the price level.

When the money wage and interest rate are perfectly flexible, output, employment, and the real wage depend only on the supply of labor and on production possibilities; the rate of interest depends only on "productivity" and "thrift" (on θ and β); and the price level depends on the quantity of money and on "liquidity preference" (the function H). Money is neutral and the quantity theorem holds.[23]

A fall in the marginal efficiency of capital (a fall in θ) will, by (31), imply a fall in the rate of interest. From (32), a fall in the rate of interest will imply a fall in the price level. In contrast with the impact effect, consumption and investment will be unaffected.[24] The real wage, employment, and output will be unaffected. The money wage will fall in the same proportion as the price level.

A fall in the marginal propensity to consume, β, will, by (31), imply a fall in the rate of interest. In (32), because both β and i have fallen, the effect on the price level is uncertain. There will be a fall in consumption and a rise in investment. The real wage, employment, and output will be unaffected. The money wage will change in the same proportion as the price level.

The classical case corresponds to Leijonhufvud's "full information macro" solution in which all of the classical propositions hold.

B. *The Wicksell Case: Money Wages Flexible, Interest Rate Stabilized*

So long as the money wage is perfectly flexible, the labor market will clear and the real wage, employment, and output will be determined independently of the rest of the system. Whatever the expected sales price of output, P^e_{t+1}, the money wage will adjust to maintain equilibrium in the labor market.

dynamic system to a comparative static one—as I will do with the Robertsonian model—it is quite another matter to try to expand a comparative static system into a dynamic one. The problem is that infinitely many dynamic systems reduce to the same comparative static system, so that it is impossible to infer the "true" dynamic system from which the latter was reduced.

[22] The labor market solution is independent of the rate of interest because (a) by our assumption of the short run, physical capital is fixed, and (b) we are ignoring the interest charge on circulating capital. See fn. 7.

[23] Because of the assumed homogeneity of H.

[24] The interest inelasticity of savings is crucial for this.

Stabilization of the interest rate involves a continuing change in the quantity of money so long as the stabilizing intervention continues. The continuing change in the quantity of money implies a continuing change in the price level. It will be shown by construction that there exists, given certain conditions, a steady state in which the quantity of money and the price level are changing at the same rate ρ.

Given constant output, the condition for clearing the market for goods is

$$(33)\quad y=\beta P_{t-1}y/P_t + I\big((1+\bar{i})/(1+\rho_t^e)-1,\theta\big).$$

In the steady state (28) and (29) obtain, so that (33) becomes

$$(34)\quad y=\beta y/(1+\rho) + I\big((1+\bar{i})/(1+\rho)-1,\theta\big).$$

It is instructive to compare equations (31) and (34). The former may be rewritten

$$(35)\qquad (1-\beta)y=I(i,\theta)$$

—the condition that saving equal investment. Equation (34) may be rewritten

$$(36)\quad (1-\beta)y/(1+\rho)+\rho y/(1+\rho) = I\big((1+\bar{i})/(1+\rho)-1,\theta\big).$$

Here, saving $((1-\beta)y/(1+\rho))$ is clearly *not* equal to investment. The condition for clearing the market for goods requires that output not consumed be invested. When prices are constant, real disposable money income equals output, so that output not consumed equals saving; when prices are changing, real disposable money income *does not* equal output, so that output not consumed does not equal saving. In a deflation, real disposable money income exceeds output by $-\rho y/(1+\rho)$, and saving exceeds investment by the same amount. This is possible because of the continuing exogenous supply of securities by the bank/speculator.[25]

Since saving and output not consumed are not the same when prices are changing, it is useful to give the latter magnitude a name of its own. Robertson called it *lacking*. Thus, the condition for clearing the market for goods is the condition that lacking equal investment. Only when prices are constant does saving equal lacking. Only then, therefore, does the condition require that saving equal investment. When the interest rate is flexible, the equilibrium condition for the goods market determines the rate of interest for which saving equals investment. When the interest rate is stabilized, the equilibrium condition for the goods market determines instead the steady-state rate of change of the price level for which *lacking* equals investment.[26]

Figure 4 shows investment, *IV*, and lacking, *LK*, as functions of ρ. The interest rate is stabilized at the rate consistent with (35) given the initial β and θ. Equilibrium ρ is zero.

Consider now a fall in the marginal efficiency of capital to θ' with i pegged at its original value. There will be a shift downward of the *IV* schedule to *IV'* and so a negative equilibrium ρ. This assumes the *IV* schedule to be less steep than the *LK* schedule, which will be the case if the interest elasticity of investment is small and the marginal propensity to consume is large. If, instead, the *IV* schedule is the steeper, the equilibrium value of ρ will be positive. We know from the single period analysis of Section II that prices will start to fall following a fall in θ. Hence, if the *IV* schedule is less steep than the *LK* schedule, the deflation will converge to the constant steady-state value

[25]Keynes, of course, *defined* saving as output not consumed, rather than as money income not spent. When prices are constant, the two definitions are equivalent; when prices are changing, they are not. The Robertsonian definition is more useful because, as we shall see, it captures an important distinction hidden by the Keynesian definition.

[26]This is a true equilibrium condition—not a truism. If the market for goods did not clear, the condition would not be satisfied. Compare Robertson (1933).

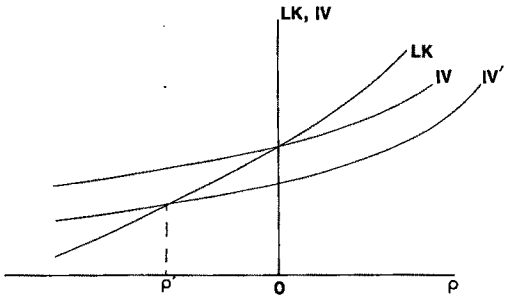

FIGURE 4. EQUILIBRIUM IN THE GOODS MARKET WITH A STABILIZED INTEREST RATE

ρ'; if not, the deflation will grow progressively worse without bound.[27] In the following we will assume the "normal" case—the *IV* schedule less steep than the *LK* schedule.

The effect of a fall in the marginal propensity to consume, β, is quite similar to that of a fall in θ. A fall in β implies a shift upwards of the *LK* schedule in Figure 4 while the *IV* schedule remains in its original position.

With the interest rate stabilized by the bank/speculator, the condition for equilibrium in the uses of money is, from (22),

$$(37)\quad (M_t+\Delta M_t)/P_t = y+H\big(\beta y/(1+\rho),\bar{i}\big).$$

In the steady state, the right-hand side of (37) is constant, and so, therefore, is the left-hand side. The quantity of money in circulation must be changing at the same rate ρ as is the price level. When the quantity of money in circulation is given and the interest rate flexible, the condition for equilibrium in the uses of money determines the price level. When the rate of interest is stabilized, this condition determines instead the rate of change of the quantity of money, now an endogenous variable.

In the previous, classical, case, when the price level was constant, it was true both that saving equalled investment and that saving equalled the supply of loanable funds. As we have just seen the former equality does not hold in the Wicksell case. The latter equality does not hold either. This may be seen by combining identities (2) and (4) to obtain

$$(38)\quad B_t^H/P_t \equiv (1-\beta)y/(1+\rho) - \rho H\big(\beta y/(1+\rho),\bar{i}\big)/(1+\rho).$$

The real supply of loanable funds is the sum of the real value of saving and of the real value of the money reduction in idle balances (called *dishoarding* by Robertson). To keep the real value of idle balances constant, they must be reduced in money terms. This dishoarding provides an additional supply of loanable funds.[28]

C. *ISLM: Money Wage Rigid, Interest Rate Flexible*

As a result of the rigidity of the money wage, the labor market equation may no longer be solved independently of the other equilibrium conditions. Given the fixed money wage, the value of the price level determines the real wage, and so employment and output. The relationship between the price level and the resulting output is shown as the curve *S* in Figure 5b.[29]

If the price level is regarded as given, then (31) and (32) may be interpreted as the standard *IS* and *LM* conditions in terms of output and the rate of interest. The two schedules are shown in Figure 5a, with the intersection providing the solution values for y and i, given P. The relationship between the given price level and the solution value of y in Figure 5a is shown as the curve *D* in Figure 5b. The system is initially in equilibrium at i_0, P_0, y_0.

Consider a fall in the marginal efficiency of capital. This shifts the *IS* curve down to

[27]Convergence assumes, of course, a stable expectations mechanism.

[28]It is assumed here that all dishoarding is channelled into the purchase of additional securities. Had we included capital gains on idle balances in disposable income (see fn. 10), a fraction β of dishoarding would have gone into additional consumption and only the remainder into securities. Under that definition of disposable income, saving *would* equal the supply of loanable funds even in the Wicksell case.

[29]The slope of *S* is $-F'\bar{W}/F''P^2$, which is positive.

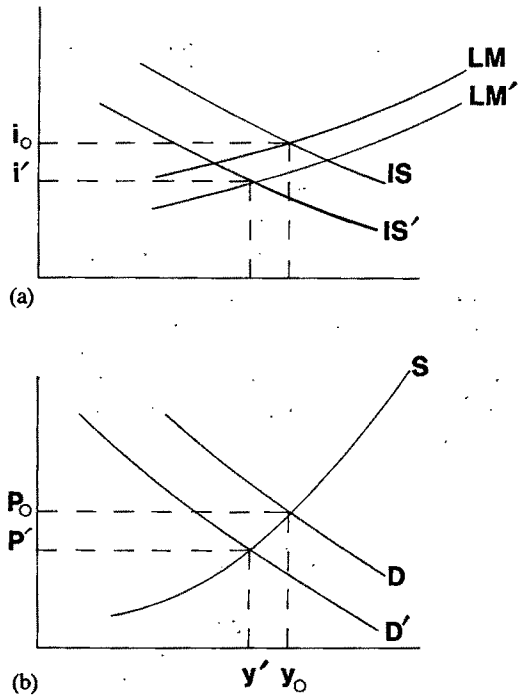

FIGURE 5. *ISLM* WITH A FLEXIBLE PRICE LEVEL

IS′ and the *D* curve down to *D′*. The result is a lower equilibrium output, *y′*, and a lower equilibrium price level, *P′*. The fall in the price level shifts the *LM* curve to the right to *LM′* to give an equilibrium interest rate of *i′*. A fall in the marginal propensity to consume will shift both the *IS* curve and the *LM* curve downwards for a given *P*, so that the effect on the *D* curve is uncertain. Hence, the effect on output and on the price level is uncertain. It can be shown, however, that the interest rate must fall.[30] This analysis is very similar to the Modigliani version of *ISLM*.[31]

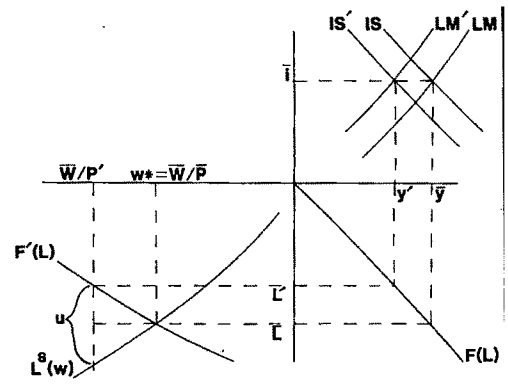

FIGURE 6. UNEMPLOYMENT EQUILIBRIUM

D. *The Keynes-Leijonhufvud Case: Money Wage Rigid, Interest Rate Stabilized*

The economy is in short-run equilibrium at its natural rate of interest and full employment. The south-west quadrant of Figure 6 shows the labor market in equilibrium at the real wage $w^*=\bar{W}/\bar{P}$. At this wage, (full) employment is $\bar{L}$ and output, from the production function in the south-east quadrant, is $\bar{y}$. Given this output, the *IS* and *LM* conditions are satisfied at an interest rate of $\bar{i}$, as shown in the north-east quadrant.

Now suppose there is a fall in the marginal efficiency of capital—a downward shift in the *IS* curve to *IS′*—with the interest rate pegged at $\bar{i}$ by the bank/speculator and the money wage remaining fixed at $\bar{W}$. From the analysis of the impact effect, we know that the price level will fall. As a result, the real wage will rise and employment and output will fall. This cumulative decline will continue until output falls to *y′* and saving once

[30]The conditions are $dy/d\beta-(I_1/(1-\beta))di/d\beta=I/(1-\beta)^2$; $-(1+H_1\beta)dy/d\beta-H_2di/d\beta=H_1y$.

[31]The Hicks' version assumes *P* fixed as well as *W*, but this is less faithful to the *General Theory*. Compare Hicks:

> One could construct a model in which only the market for labor was a fixprice market, and not only the rate of interest but also the price (or price level) of finished products was flexible. It is possible that Keynes himself sometimes thought in terms of that sort of model [see, for example, Keynes, 1936, ch. 21]; but it cannot be this which *IS-LM* is supposed to represent. For *Y* is taken to be an index not only of employment, but also of output, so the prices of products also are supposed to be fixed in terms of the standard; and it is hard to see how that can be justified unless the prices of products are derived from the wage of labor by some markup rule. But if that is so, we have not one, but two, fixprice markets.
>
> [p. 145]

Most textbooks adopt the Hicks version. One exception is William Branson's. His analysis differs from the current one in only two respects: (a) a change in the price level shifts his *IS* curve as well as his *LM* curve because of a wealth effect—there are no wealth effects here; (b) Branson's liquidity preference function depends on real income rather than on consumption as is the case here.

gain equals investment, satisfying the *IS* ondition. (In the interim the goods market ill continue to clear, but, with a constantly alling price level, saving will not equal investment.) The equality of saving and investnent implies that no further intervention by he bank/speculator is necessary to hold the nterest rate at $\bar{i}$, and, therefore, that the uantity of money in circulation and the rice level will stop falling.[32] The new equiibrium price level is P'. The *LM* curve will ave shifted to the left to LM' to intersect S' at $(y', \bar{i})$. This solution is the "unemploynent equilibrium" of Leijonhufvud and Keynes: the markets for goods and for oanable funds clear, only the market for abor does not.

E. *The Unemployment-Deflation Case: Money Wage Sticky, Interest Rate Stabilized*

The money wage is assumed to adjust ccording to (17). In the steady state, wages re changing at the rate ρ, so that

$$W_t = (1+\rho)W_{t-1}. \tag{39}$$

Substituting (39) into (17) and dividing hrough by P^e_{t+1} we have

$$w = w^*\alpha(1+\rho)/(\alpha+\rho). \tag{40}$$

Note that both w^* and w lack time subscripts as they are constant over time.

Stabilization of the interest rate by the bank/speculator at a level above that required to clear the market for loanable funds will exert a persistent deflationary pressure on the economy. If the money wage is sticky, the deflationary pressure will result not only in a falling price level, but also in unemployment and a fall in output. The price level will be falling because of the continuing fall in money aggregate demand, while the money wage will be falling in response to excess supply in the labor market.[33]

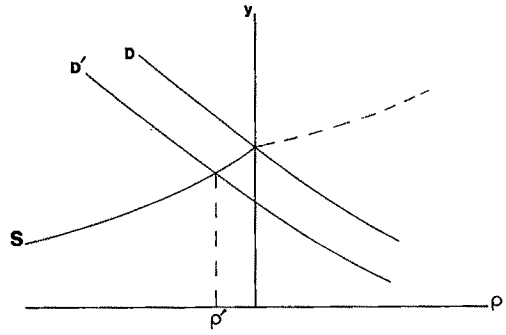

FIGURE 7. SIMULTANEOUS SOLUTION OF CONDITIONS FOR THE GOODS AND LABOR MARKETS

If the money wage is falling at the same rate as the price level, the real wage will remain constant, and the economy will be in a deflationary steady state with constant unemployment. The existence of such a steady state may be shown by construction.

Steady-state output depends on the rate of deflation through the effect of the latter on the real wage through (40). This relation between y and ρ is the "supply" curve, S, in Figure 7.[34] The corresponding "demand" curve — representing equilibrium in the market for goods—may be derived from the lacking-equals-investment condition, (36).[35] In Part *B* above, with the money wage perfectly flexible, output is fixed at its full employment level, and the lacking-investment condition determines the steady-state rate of deflation. Here, because the money wage is sticky, y and ρ are determined jointly by the

[32]In terms of Robertson's exposition, discussed in the introduction, the quasi-natural rate has been brought up all the way back to the original natural rate. Figure 1 shows the market "excluded" from Figure 6.

[33]This is not quite the modern Keynesian story. In the latter, the goods market fails to clear. This leads to layoffs, leading to a fall in the money wage, leading to a fall in the price of goods which is a markup over labor costs.

[34]The formula for the supply curve is

$$y = F\left(F'^{-1}\left(w^*\alpha(1+\rho)/(\alpha+\rho)\right)\right);$$

its slope is

$$dy/d\rho = -(1-\alpha)\alpha^2(1+\rho)w^{*2}/(\alpha+\rho)^3F'',$$

which is positive for $\rho > -\alpha$. The continuation of the curve into the positive quadrant is drawn as a dashed line, since the behavior of the system under inflation and excess demand has not been analysed here. See my 1981b paper for a discussion.

[35]The slope of the demand curve is

$$\left(-\beta y - (1+\bar{i})I_1\right)/(1+\rho)(1+\rho-\beta),$$

which is negative if $\rho > -(1-\beta)$ and if the *LK* schedule is steeper than the *IV* schedule (the "normal" case—see Part B above).

equilibrium conditions for the market for labor—the supply curve—and the market for goods—the demand curve. If the interest rate is "stabilized" at the natural rate (no intervention being necessary, of course, to do this) the demand and supply curves will cross on the y axis at full employment y, and the price level will be constant.

Consider now a fall in the marginal efficiency of capital or in the marginal propensity to consume with the interest rate stabilized at its original level by the bank/speculator. The demand curve will shift downwards to D'.[36] The new short-run solution will be a steady state with both the price level and money wages falling at the rate ρ'. The real wage will remain above its market-clearing value, w^*, and unemployment will persist. Output will be below its full-employment level. The analysis of Section II, Part B indicates that the impact effect of such a change will push the economy in the "right" direction, so that if expectations are stable, the economy will approach this steady state.

The effect of the degree of stickiness of money wages on the nature of the short-run solution may be seen by examining the dependence of the slope of the supply curve on the parameter α. At the y axis this slope is[37]

$$(41) \quad dS/d\rho|_{\rho=0} = -((1-\alpha)/\alpha)w^{*2}/F''.$$

If α is unity, the money wage is perfectly flexible and the supply curve is horizontal. This corresponds to the Wicksell case: a fall in the demand curve (in θ or in β) will result in a steady-state deflation but no unemployment. If α is zero, the money wage is completely rigid and the supply curve is vertical. This corresponds to the Keynes-Leijonhufvud case: a fall in the demand curve will result in persistent unemployment *with constant prices* (with ρ zero). For all intermediate values of α there will be both a steady-state deflation and persistent unemployment.

[36]Had the interest rate been allowed to adjust, only the slope of the demand curve would have changed: it would still have intersected the supply curve at full-employment output.

[37]This is the left-hand derivative at $\rho=0$.

IV. Discussion

The impact and short-run effects of a fal in the marginal efficiency of capital and of a fall in the marginal propensity to consum under the various assumptions about th flexibility of the money wage and of the rat of interest are summarized in Table 1.

A. *Unemployment Equilibrium*

Leijonhufvud suggests that the main con tribution of the *General Theory* was to estab lish the possiblity of "unemployment equi librium." A fall in the demand for loanabl funds (because of a fall in θ) would lead through the income-expenditure mechanism to a fall in the supply of loanable funds. I the interest rate was supported *temporaril* by the bank/speculator, the quasi-natura rate would rise to the stabilized level of th market rate, making further support unnec essary. Although the market rate would b above the true natural rate, there would b no excess supply in the market for loanabl funds, and so no pressure on the market rat to fall. Only in the labor market would there be disequilibrium.[38]

We have seen that this possibility does indeed exist, but *if, and only if, the money wage is completely rigid.* If there is any wage flexibility at all, the short-run solution will involve a *persistent* excess supply of loanable funds. As a result, the downward pressure on the interest rate will remain. If the bank/speculator is at all sensitive to this pressure—and Leijonhufvud himself explains why the bank/speculator should be—then the interest rate will fall towards its quasi-natural level, and the latter will in turn fall towards the true natural rate. If there is any flexibility at all in the money wage and in the market rate of interest, this process will end only when full employment is re-established.

[38]"At full employment, there will be unrelenting pressures towards correction of any 'unnatural' rate of interest—but otherwise not... With the interest rate at the right level, market forces should make unemployment converge on its natural rate—but otherwise not" (Leijonhufvud, p. 42).

TABLE 1—THE IMPACT AND SHORT-RUN EFFECTS OF EXOGENOUS CHANGES UNDER VARIOUS ASSUMPTIONS

	i	P	w	L	y	I	ρ
A. Flexible i, flexible W							
a) $\theta\downarrow$ Impact	↓	↓	=	=	=	↓	
Short Run	↓	↓	=	=	=	=	0
b) $\beta\downarrow$ Impact	↓	?	=	=	=	↑	
Short Run	↓	?	=	=	=	↑	0
B. Stabilized i, flexible W							
a) $\theta\downarrow$ Impact	=	↓	=	=	=	↓	
Short Run	=		=	=	=	↓	<0
b) $\beta\downarrow$ Impact	=	↓	=	=	=	=	
Short Run	=		=	=	=	↓	<0
C. Flexible i, rigid W							
a) $\theta\downarrow$ Impact	↓	↓	↑	↓	↓	↓	
Short Run	↓	↓	↑	↓	↓	↓	0
b) $\beta\downarrow$ Impact	↓	?	?	?	?	↑	
Short Run	↓	?	?	?	?	↑	0
D. Stabilized i, rigid W							
a) $\theta\downarrow$ Impact	=	↓	↑	↓	↓	↓	
Short Run	=	↓	↑	↓	↓	↓	0
b) $\beta\downarrow$ Impact	=	↓	↑	↓	↓	=	
Short Run	=	↓	↑	↓	↓	=	0
E. Stabilized i, sticky W							
a) $\theta\downarrow$ Short Run	=		↑	↓	↓	↓	<0
b) $\beta\downarrow$ Short Run (Impact as in D.)	=		↑	↓	↓	↓	<0

A slightly different argument for unemployment equilibrium put forward by Keynes and by Leijonhufvud is that unemployment once established—say by temporary wage rigidity—could not be eradicated by any amount of reduction of the money wage.[39] It is argued that the reduction in money wage will lead to a reduction in aggregate money demand, and so in prices. Consequently, the real wage will not fall, and unemployment will persist. Note first that this argument makes no sense at all in the context of the single period because a reduction in money wage has no effect on money income, which is predetermined. Of course, price expectations could be so sensitive to the money wage that the real wage would not be able to fall far enough to clear the labor market. However, barring this possibility, complete flexibility of the money wage must restore full employment within the single period.

[39] "Perfect flexibility could prevent unemployment from developing to begin with—but it will not remove it once you have it" (Leijonhufvud, p. 10, fn. 50).

The intention of the argument, then, must be that a relaxation of wage rigidity will not bring about a full-employment equilibrium *in the short run*. Our results do not support this. Starting from an unemployment equilibrium, suppose that the money wage begins to adjust (α becomes positive). Employment will begin to rise, and disequilibrium will immediately reappear in the market for loanable funds, with the concomittant pressure on the bank/speculator to allow the interest rate to fall. If the bank/speculator resists this pressure, the economy will approach a short-run steady state with both unemployment and deflation. If the bank/speculator gives in to the pressure, as is to be expected, the economy will approach a full-employment short-run equilibrium.

In the Keynesian theory there are two mechanisms by which deflation tends to restore full employment. The first is the "Keynes effect." A fall in the money wage leads to a fall in the price level, which leads to a fall in the demand for nominal money balances. This in turn leads to a fall in the interest rate, which stimulates investment,

and so employment. If the bank/speculator prevents the interest rate from falling, this sequence is blocked. Appeal must then be made to the second mechanism—the "Pigou effect." Falling prices raise the real value of "outside" obligations, and the resulting increase in wealth leads to a rise in the marginal propensity to consume out of income.

In the loanable funds theory there is a third mechanism—the "Robertson effect." Deflation will raise the real value of disposable money income from y to $y/(1+\rho)$, with a consequent increase in consumption.[40] This is not a wealth effect: it will work even in a pure inside-money economy of the Wicksell type in which the Pigou effect is inoperative.

B. *The Compatibility of Unemployment Equilibrium and the Loanable Funds Theory of Interest*

By accepting unemployment equilibrium, but rejecting the bootstrap liquidity preference theory of interest, Leijonhufvud is trying to eat his cake and have it too. If unemployment equilibrium is possible, then *any* rate of interest supported temporarily becomes a quasi-natural rate. The supply of loanable funds is brought into equality with demand at the supported rate through the adjustment of income, and further support becomes unnecessary. In this case, the supply and demand for loanable funds determine income, not the rate of interest. If one accepts the possibility of unemployment equilibrium, one has to accept, with Keynes, some bootstrap theory of interest in place of the loanable funds theory.[41] The liquidity preference theory—that the interest rate is what speculators expect it to be—fits the bill well enough.[42] One may disagree with Keynes, but one has to recognize the internal consistency of his theory.

C. *The Paradox of Thrift*

In the *General Theory* it is suggested not only that disequilibrium in the loanable funds market will prevent the labor market from functioning properly, but also the converse—that disequilibrium in the labor market will prevent the loanable funds market from functioning properly. If the economy is not at full employment, an increase in the propensity to save will result, not in an increase in investment, but in a decrease in output. This is the "Paradox of Thrift."[43]

A glance at Table 1 will show that this proposition is not supported by our analysis. So long as the rate of interest is allowed to adjust freely, a fall in the marginal propensity to consume will bring about a fall in the rate of interest and an increase in investment whether or not the money wage is rigid (whether or not there is unemployment).[44] If the interest rate is stabilized and the money wage rigid, investment will remain the same and output will fall; if the money wage is sticky, investment will fall as well as output; if the money wage is flexible, investment will fall while output remains the same. This *fall* in investment—a Paradox of Thrift with a vengeance—is a result of the rise in the real rate of interest because of the deflation. In these latter cases, it is the intervention of the bank/speculator in the loanable funds market, not disequilibrium in the labor market, which prevents the increased propensity to save from being translated into increased investment. This is, of course, no paradox.

[40]Investment will actually fall because of the rise in the real rate of interest. If the effect on consumption is the stronger—the condition needed for the existence of a deflationary steady state—then total aggregate demand will be stimulated.

[41]See fn. 2 above.

[42]The pure bootstrap theory corresponds to the "extreme Keynes" case in the textbooks—that is, a horizontal *LM* curve. More generally, in *ISLM* analysis, the interest rate is determined by a combination of bootstrap (*LM*) and productivity-thrift (*IS*) elements.

[43]For example, Keynes wrote: "Up to the point where full employment prevails, the growth of capital depends not at all on a low propensity to consume but is, on the contrary, held back by it; and only in conditions of full employment is a low propensity to consume conducive to the growth of capital" (1936, pp. 372–73).

[44]Keynes later conceded that a fall in the propensity to consume would lower the interest rate, but maintained that it would also increase unemployment (see the exchange between Keynes and Robertson in the 1938 *Economic Journal*). Our model suggests that the effect on unemployment is ambiguous.

D. *Loanable Funds, the General Theory, and Monetary Disequilibrium*

While Leijonhufvud is quite right in seeing he *General Theory* as an unfortunate departure from the business cycle theory that preeded it—as well as an important advance, f course—his identification of the nature of hat departure is not quite correct. In terms f the theory developed here, the business ycle literature that preceded the *General heory* could be seen as variations on the ingle period sequence analysis of Section II. he main *analytical* problem with this type f sequence analysis was the difficulty of ollowing it through to some sort of final onclusion. It was possible to trace through he sequence of events for the first few periods, but then the analysis bogged down. usiness cycle theorists were reduced to conecture about the ultimate effects of an exognous change, and that conjecture was frequently wrong.[45]

Keynes was able to solve this analytical roblem by applying a new theoretical result nd by changing somewhat the nature of the uestion being asked.[46] The new theoretical esult came out of Richard F. Kahn's study f the multiplier process. There was, of ourse, nothing new in multiplier effects per e: they played an important role in the equence analyses of Wicksell, of Robertson, nd of the *Treatise*. What was new, however, as the realization that the multiplier proess *converged*.[47] This realization now made t possible to talk about the new position of est following an exogenous change, when he process of adjustment described by the equence analysis had worked itself out. In erms of our own analysis, it became possible o move from the single period to the short un.

[45]See, for example, Keynes' famous analysis (ch. 14, Vol. 1, of the *Treatise*) of a "thrift campaign" (an increase in the propensity to save) in a "Banana republic." He concluded that, in the absence of a rise in investment, the cumulative contraction could end only when production had been driven to zero.

[46]This interpretation of the analytical advance embodied in the *General Theory* owes much to Lucas (1980b).

[47]This point was made by Patinkin in an address to the Israel Economics Association in 1976.

In spite of its name, the *General Theory* did not develop a general short-run solution. That was where the change of question came in. Before the *General Theory*, the aim of business cycle theory had been to explain the cycle as a whole. Keynes chose instead to focus on the contractionary phase,[48] and to do so under the very special assumption of money-wage rigidity. The *General Theory was* a generalization in that it demonstrated the existence of short-run solutions other than the classical one. It was not, however, a *complete* generalization: it did not encompass all possible short-run solutions.

The way to a general short-run solution, or to a comprehensive set of special short-run solutions, is to apply Keynes' method without adopting his change of question or his special assumptions. By starting from the Robertsonian sequence analysis and imposing convergence of the multiplier process and of the adjustment of expectations, it is possible, as we have seen, to generate a wide variety of short-run solutions. This "loanable funds theory" includes the solutions considered by Keynes as special cases.

The short-run solutions generated in this way may be divided into two categories—monetary equilibrium and monetary disequilibrium. The first category includes the classical case, *ISLM*, and the Keynes-Leijonhufvud case. All of these are closed static equilibria in which no continuing outside intervention is involved. Because *ISLM* and the Keynes-Leijonhufvud case are of the same type of equilibrium as the classical case, they are amenable—as sequence analysis and monetary disequilibrium are not—to the same type of neo-Walrasian analysis.[49] It is this similarity which justifies the claim that the *General Theory* represents an empirically important, but theoretically trivial, variation on the classical solution based on the special assumption of a fixed money wage.

The second category of short-run solution, monetary disequilibrium, includes the Wicksell and unemployment-deflation cases. Although a monetary disequilibrium is a

[48]It could even be argued, as Allan Meltzer does, that Keynes focused on *stagnation* or permanent contraction.

[49]Compare Clower (1975).

position of rest, it is not a closed static equilibrium, but a static *dis*equilibrium representing a complete adjustment to a *continuing* outside intervention. (A comparable example from physics would be a metal rod heated at one end to produce an equilibrium heat flow and an equilibrium temperature gradient.) In a monetary disequilibrium the continuing outside intervention takes the form of the continuing external supply of securities to satisfy the continuing excess supply of loanable funds, with the consequent continuing leakage of money out of circulation, and continuing fall in the price level. The economy is fully adjusted to this continuing intervention. However, if the intervention were to cease, the economy would not remain in the same state, but move, rather, to the appropriate closed static equilibrium.

The failure to distinguish between these two categories of solution, and to recognize that the *General Theory* belongs to the first, has led to some confusion. A particularly illuminating example occurs in Franco Modigliani's justly famous exposition of the *General Theory*. He concedes to Keynes that with a fully stabilized interest rate "the Keynesian theory of liquidity preference is sufficient by itself to explain the existence of underemployment without starting out with the assumption of rigid wages" (p. 74). Modigliani argues that the addition of the condition $i=\bar{i}$ leaves his system of equations overdetermined and that, therefore, unemployment must somehow result. In the current framework, this is equivalent to adding the condition $i=\bar{i}$ to the solution conditions for the classical case—equation (30a), (30b), (31), and (32). Modigliani's error was his failure to realize that if the interest rate is stabilized, equations (31) and (32) *are no longer relevant*. They must be replaced with equations (34) and (37), the equivalent equations for a monetary *dis*equilibrium. An additional variable, ρ, is introduced, and there is therefore no overdetermination. Modigliani's concession on the necessity of a rigid money wage for Keynes' results was mistaken.

The acceptance of the *General Theory* did result, as Leijonhufvud suggests, in the loss of a major component of monetary theory The loss, however, went far beyond th loanable funds theory of interest to includ the whole infrastructure of sequence analysi on which the loanable funds theory reste The Robertson-Wicksell sequence analysis unlike the Keynesian short-run solution, wa not readily amenable to the newly popula neo-Walrasian mode of analysis, and, as result, it was soon forgotten. Some twent years later the quest began for the "micro foundations" of macro theory, for the "es sential" role of money, for the dynamic behind the comparative statics of *ISLM* They are all there in the pre-*General Theor* sequence analysis, waiting to be redis covered.

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Rawlsian Justice as the Core of A Game

By ROGER E. HOWE AND JOHN E. ROEMER*

A natural way of formally describing the idea of a social contract is as the core of a game. Consider the members of society as the participants in a game with many players. Every coalition of people could, on its own, make available to its members a certain amount of income (or goods) if it withdrew from society and operated as a mini society on its own. A game (in characteristic form) may be defined by specifying what the income (or payoff) would be to each coalition, if it were to withdraw from society. Consider, now, an allocation of income, an income distribution, for all of society. If there is no coalition which can better the lot of all its members by exercizing its withdrawal option, then the given income distribution is said to be in the *core* of the game. The core is the set of all income distributions which cannot be "blocked" by any coalition by withdrawal as described.

We say the core captures the idea of social contract because it recognizes the conflicting aspects of cooperation and necessity which are at the heart of the contractarian notion. An allocation in the core is one which all members agree to abide by, not because it is in some sense marvelous for every individual, but because there is no way that any group can organize to gain a superior position for its members, *given the rules of organization* and hence payoffs to which society's members have agreed. Clearly what differentiates one social contract from another are the payoffs that society specifies and which embody its ethics. Society must adopt a rule for assigning any coalition its "dowry," should it decide to withdraw; these payoffs to coali tions define the game. For instance, a partic ular social ethic might entitle each coalition should it withdraw, to the original endow ments of its members. Or, alternatively society might prescribe that a withdrawin coalition be entitled to its per capita share o total social endowment. These two with drawal rules define different games, with dif ferent social contracts; there are, of course many more possibilities. The rule by whic society specifies the hypothetical dowry o any coalition embodies society's ethical no tion of what the coalition is entitled to, shoul it decide to opt out of society. One can thin of a particular ethical premise to entitlemen as defining the property rights that a societ considers ideal. The core of the game is the the collection of allocations corresponding t the entitlement conception which the gam specifies, as no coalition can, through its ow actions, improve the lot of its members un der those entitlements, starting from any al location in the core.

Note the game which specifies society' conception of entitlements is hypothetical i this sense: it need not be possible for a coalition actually to withdraw with its as signed dowry. (Indeed, the essence of *societ* is that such withdrawal is in practice impos sible or extremely costly.) We envisio society's members agreeing to the social con tract because they are assured at least a certain payoff. Rawls formalizes this precon tractarian agreement as occurring before th veil of ignorance is lifted.

The rule which society adopts to define th hypothetical payoffs to its coalitions embod ies its ethical presumption. A contractarian concept of justice is described by specifying a game; an allocation in the core of that game is then a just allocation, as it cannot be improved upon by any coalition under the hypothetical alternative of exercising its ethical right. These observations invite the fol-

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owing question. Given a contractarian theory of justice, what is the game whose core consists of precisely the just allocations of the theory in question?

In this paper, we give an answer to this question for Rawlsian justice. When Rawls maintains that rational individuals would agree, in a certain pristine state, to a particular income distribution (the maximin one), he is suggesting there is a social contract giving rise to that distribution. If we think of individuals as taking part in a lottery for natural endowments behind the veil of ignorance, the outcome of which will determine their potential for generating income (and hence access to "primary goods"), the game structure of the problem becomes evident. We will allow an individual or a coalition of individuals to express its dissatisfaction with a particular income distribution by hypothetically withdrawing from society, and testing whether under the rules of the game it can improve the lot of its members. We seek rules of the game which will generate as the core precisely the maximin income distribution(s).

This approach allows us to evaluate the Rawlsian theory of justice in a detached way, since the ethical content of the theory must be embodied in the *criteria for withdrawal* which define the game. In fact, we shall see the Rawlsian criteria are only one possible set, and that other apparently reasonable withdrawal criteria imply other social contracts in the Rawlsian environment.

The outline of the paper is as follows. In Sections I and II, the Rawlsian problem is modeled and the game is exhibited whose core consists of the maximin distributions. In Section III, we show the Rawlsian game lies naturally in a continuum of justice games, gotten by varying the degree of risk aversion of the agents. Section IV looks more explicitly at various taxation schemes which are optimal in the Rawlsian sense, and displays some troublesome features of the maximin distribution. In Section V, we raise questions concerning the consistency of the Rawlsian theory of justice as a contractarian theory, and conclude that, as stated, it is inconsistent. Although the method is quite general, this paper concentrates on Rawlsian justice. We briefly indicate the application of the technique to other concepts of justice, fairness, and exploitation.

I. A Model of the Rawlsian Problem

To model the Rawlsian problem, it is convenient to view individuals in society as points α of a multidimensional continuum A whose coordinate axes represent relevant socioeconomic characteristics. We will be more explicit below about what these characteristics are. Individuals are distributed in this continuum according to some probability distribution $d\alpha$. Behind the veil of ignorance, individuals do not know where they will be placed in the social continuum, but they know there is such a probability distribution $d\alpha$. They need not know the explicit form of $d\alpha$, however.

Associated with individual α is a natural wage, $\omega(\alpha)$, which is the amount of income α can produce in unit time. The parameter α can now be thought of as including information on the individual's skills or income producing capacity; in addition, it can contain information on his preferences for leisure versus income, although that information is not needed to determine his natural wage. Income is taken as the proxy for primary goods. In particular, income is not a measure of utility, a point of importance. We are concerned with redistributing these incomes which are produced initially once people get their endowment assignments and model this redistribution as a tax on income. Thus we imagine various possible *tax schemes* $\tau = \tau(\alpha, Y)$ which specify the tax to be levied on a person with characteristics α and income Y. There are many possible tax schemes, and already in this simplified model we will see what types of tax schemes one is willing to admit or imagine becomes an issue. There is a substantial literature on optimal taxation and it is not our purpose to become involved in the technicalities of that discussion. We will consider various extreme cases and note the variety of worlds they would produce, even following Rawls' general prescription.

Thus, at a very basic level, the issue of mechanisms of redistribution (taxation) must be addressed, if one is to base policy on a theory of the Rawlsian type.

Facing a tax scheme $\tau(\alpha, Y)$, an individual of type α will choose to work a certain amount of time $l(\alpha,\tau)$ and thereby produce a certain income $Y(\alpha,\tau)=\omega(\alpha)l(\alpha,\tau)$. Of this, $\tau(\alpha,Y(\alpha,\tau))$ will go for taxes and the individual will be left with $Y(\alpha,\tau)-\tau(\alpha,Y)$ in after-tax income. For some individuals τ will be negative and thus be a subsidy. Clearly, whatever its individual peculiarities, any tax scheme should satisfy the basic accounting principle that revenue received is revenue disbursed. Thus we make the following definition:

A feasible tax scheme $\tau(\alpha,Y)$ is a system of redistribution that precisely balances. The tax revenues should equal the expenditures (to the subsidized). τ is a feasible tax scheme, if

$$\int_A \tau(\alpha, Y(\alpha,\tau))\, d\alpha=0.$$

Each feasible tax scheme gives rise to a post-tax income distribution. We formulate now the definition of the maximin distribution(s). Given a feasible tax scheme $\tau(\alpha,Y)$, an income distribution is produced with a certain smallest after-tax income. The problem is to find that distribution which maximizes this minimum income. We call this maximin income Y_{min}, defined by

$$Y_{min}=\max_{\tau\, feasible}\ \min_{\alpha}\left(Y(\alpha,\tau)-\tau(\alpha,Y(\alpha,\tau))\right)$$

Several remarks are in order. In Section IV below, when we solve for the maximin distribution, we will wish to restrict ourselves to smaller classes of tax schemes than the universe of all feasible ones, for reasons explained there. Second, it must be reiterated the social welfare criterion here employed is maximin income, not maximin utility, and therefore differs from some interpretations of the Rawlsian criterion. Rawls is quite explicit on this.[1] (We discuss further the choice of income as maximand in Section V.) Third, in choosing something called income as the maximand, and not a vector of primary goods, we avoid problems of aggregation which can lead to other problems in the Rawlsian theory.[2]

II. Justice as the Core of a Game

The veil of ignorance is the key notion in Rawlsian justice, and we formulate a game involving it as follows. Individuals behind the veil of ignorance wish to choose a tax scheme τ (or choose rules for choosing a tax scheme if they do not know the distribution $d\alpha$) with the following property: that after the lottery for α is taken, and after post-tax incomes are realized according to the chosen tax scheme, no coalition of agents would be able to guarantee an improvement in after-tax income for all its members by withdrawing again behind the veil of ignorance and trying another draw on the lottery for α. The *criteria for withdrawal* which define the game are: a coalition blocks an allocation if it can *guarantee* an allocation of income for its members which improves all its agents' incomes, if its members could withdraw again behind the veil of ignorance and take the outcome of the lottery performed for the coalition from the same distribution of endowments α. Before conducting the hypothetical second draw, the coalition is free to assign itself any tax scheme feasible for it. To put the criterion slightly differently: *society* will not accept a proposed allocation (i.e., a proposed tax scheme) if, given that tax scheme, a coalition would emerge which

[1]Rawls writes:

The essential point though is that in justice as fairness the parties do not know their conception of the good and cannot estimate their utility in the ordinary sense. In any case, we want to go behind de facto preferences generated by given conditions. Therefore expectations are based upon an index of primary goods and the parties make their choice accordingly. The entries in the example are in terms of money and not utility to indicate this aspect of the contract doctrine. [p. 155]

[2]Charles Plott assumes a vector of primary goods, and assigns agents preference orderings for comparing various vectors. He thereby forces the Rawls problem into the mold of the Arrow impossibility theorem and proves an impossibility result for Rawlsian justice. We believe this is not in the Rawlsian spirit, as Rawls wishes to avoid problems of preferences, anchoring his theory on something less subjective (primary goods). Hence, our choice of a scalar measure of income.

ould claim a *guaranteed* improvement in come for its members under some other tax roposal, if that coalition could draw again om the lottery for α. We call this kind of lock the *ERA* block, and the game is the *RA* game (*ERA* stands for extremely risk verse).

We posit a continuous model to capture e problem for this reason: it must be true at any coalition can avail itself of the same robability distribution of endowments $d\alpha$ s the universal coalition. In the continuous nvironment this is so, if we limit ourselves o the coalitions of positive measure. Indeed, is limitation can be thought of as agreeing ith Rawls' intention to consider only coalions of significant size. (We will show that r various classes of taxation schemes, the orst off coalition does have positive meaure.) Because of the continuous environent, the following is required:

efinition. A distribution is maximin if it has t most a null set of agents receiving incomes ss than Y_{min}.

Note also that when the above criterion r withdrawal is stated, we must insist that blocking coalition be able to improve the come of almost every member, not every ember, as informally stated above. ometimes in economics one stipulates that a alition can block an allocation if it can nprove the income of some members, and ot reduce the income of any member. Hower, one should note that this weak form of locking is only justifiable if it can be transrmed into *strong* blocking, by taking a little f the increment in income of the strictly etter off members, and redistributing it to ll the other members. In our model, this edistribution is illegitimate, since taking a ttle income from one member will affect his centive, and change the amount he prouces. Thus, the importance of incentives in e Rawlsian problem nullifies the equivance of weak and strong blocking. The roper notion of blocking must be strong locking, where almost every member can nprove his income.[3]

[3]It might be objected that, if an agent can be assured f not faring worse than currently, he will join a coalition which is trying to block. This belies the extreme risk-averse assumption on agents, who only join if they can be guaranteed of doing better. If there is some infinitesimal transaction cost, an extremely risk-averse agent will only join if he can be guaranteed a strict improvement.

We now prove that the *ERA* game is equivalent to the Rawlsian theory of justice.

THEOREM 1: *The core of the ERA game consists precisely of the maximin distributions.*

PROOF:

We show first that any maximin distribution is in the core. Let $Y(\alpha, \tau)$ be such a distribution and consider the coalition W of agents who receive income Y_{min} or less:

$$W = \{\alpha | Y(\alpha, \tau) \leq Y_{min}\}.$$

Case 1: *W is a coalition of positive measure.* We show W cannot block the distribution under *ERA* rules. If W tries the lottery again, the production possibilities that will be open to it are the same as society as a whole enjoys—that is, it can draw from the same distribution $d\alpha$. (This assumption may be thought of as a form of constant returns to scale: W, being itself a continuum, is simply a scaled-down version of society. More generally, what increasing returns exist have already been fully exploited by any coalition which is large (of positive measure).) After the lottery is taken for W, the coalition can assign itself various income distributions. If it assigns itself a maximin distribution, then there will be a subcoalition $W^* \subseteq W$ of positive measure which receives precisely Y_{min}, by assumption. Since W^* is nonnull, almost all of its agents were receiving Y_{min} in society's original lottery, and so they were not made better off by the withdrawal. If W chooses for itself an allocation which is not maximin, then some nonnull subcoalition of W receives income strictly less than Y_{min}, and hence those agents are strictly worse off than they were in the original allocation $Y(\alpha, \tau)$. Hence the coalition W cannot *ERA* block the distribution, as there is no allocation of income in W which improves the lot of almost every member.

But if W cannot block $Y(\alpha, \tau)$, then no coalition of agents can block $Y(\alpha,\tau)$, since any other candidate for a blocking coalition must contain a nonnull set of agents who receive more than Y_{min} in the original distribution. A fortiori, such a coalition cannot guarantee an improvement for its members by going back behind the veil of ignorance.

Case 2: W is a coalition of measure zero. Since only coalitions of positive measure are recognized, hence eligible for withdrawal, any coalition which would propose to block the income distribution must contain a nonnull set of members who are receiving strictly more than Y_{min}. Let W' be such a proposed coalition. If it can realize a post-tax income distribution which makes almost every member of W' strictly better off than he is in $Y(\alpha, \tau)$, then the original distribution was not maximin. (The true maximin must be the income below which no nonnull coalition of W' receives, in its alternative proposal.)

For the converse, the two cases need not be distinguished. Let $\hat{Y}$ be any income distribution in the *ERA* core, and suppose $\hat{Y}$ is not maximin. Then consider the nonnull coalition $\hat{W}$ of agents who receive less than Y_{min} under $\hat{Y}$. Assign to $\hat{W}$ a maximin distribution. Then almost every member of $\hat{W}$ is strictly better off, and $\hat{Y}$ is *ERA* blocked.

Before proceeding, we mention other ethical concepts which can be modeled as the core of a game. The traditional game posed in neoclassical economics stipulates that agents be able to withdraw with their own endowments. We call this the private ownership game; the well-known result is that competitive equilibria lie in the private ownership core. In work cited below, one of us claims that the implicit notion of exploitation in neoclassical economics is associated with allocations not in the core of the private ownership game. Another game stipulates that agents be entitled to withdraw with their per capita share of society's nonhuman assets, and their own human assets. This game characterizes Marxian exploitation: that is, allocations not in its core are precisely the ones where the coalitions which would benefit by withdrawal are Marxian exploited (their surplus value is being appropriated by another coalition). Concepts of feudal, slav socialist, and status exploitation can also b characterized, as is done in Roemer (1982 Notions of fairness which have been studie in recent years can also be modeled th way.[4] Contrasting the characteristic fun tions of these games is fruitful in exposin the content of their related ideologies, bu that cannot be pursued here.

III. Varying Risk Aversion Behind the Veil

To gain perspective on the Rawls gam we propose a risk-neutral (*RN*) game. In th *RN* game, the agents wish to maximize e pected income. Behind the veil of ignoranc a redistribution scheme, $\tau(\alpha, Y)$ is propose A coalition of agents will withdraw from th lottery if, under probability distribution *d* members can assign themselves a postlotter distribution in which every member can *e pect* to do better than he can *expect* to d under τ. This is a risk-neutral game, sinc agents are concerned only with maximizin expected income.

It can now be seen how the *ERA* game i risk averse. A coalition of agents in the *ER* game is only willing to block an incom distribution if, with probability one, i members can be made better off. The coal tion members are not willing to take *an* risks of a deteriorated position. In the *R* game, agents will block if their *expectation* i to improve their position.

In the *ERA* game, agents will have n desire to recontract after the lottery is take and the maximin distribution is assigned

[4] In Hal Varian's terminology, a c'-fair allocation i one which no coalition can improve upon, given th preferences of its members, when each coalition S i assigned a payoff of

$$v(S)=|S|\sum_{i\epsilon S}\omega^i\,(N-|S|),$$

where ω^i is the endowment vector of agent i. Varia (p. 76) defines another notion of fairness which corre sponds to the characteristic correspondence (rather tha function)

$$v(S)=\left\{\omega|\omega=\sum_{i\epsilon T}\omega^i, |T|=\leqslant |S|\right\}.$$

We thank the referee for these formulations.

'hat is, no coalition could assure an im-
›roved position for almost all its members.
n the *RN* game there will be some losers
.fter the lottery is drawn and the maximal
otal income scheme assigned. The coalition
›f agents who receive less than the mean
ncome would like to recontract, as they could
:xpect to improve their position with a new
lraw. This distinction points out the essence
›f risk aversion: the extremely risk-averse
.gents take no risks, so they will have no
egrets; some agents in the *RN* game who
ake risks will be disappointed. There will be
:oalitions, *ex post*, willing to organize a new
ottery under the *RN* rules, but no such
:oalition will exist under the *ERA* rules. This
›oints out why society must pass judgment
›n the acceptability of an income distribu-
ion proposal before the lottery has been
lrawn. If there is any risk in the agents'
›valuation of the distribution, there will al-
›ays be some who will wish to recontract
›fter the lottery. The *ERA* rules are the only
›nes in which no coalition will wish to recon-
ract after the lottery, and this is precisely
›ecause no risks are taken.

Note that the expectation of income is
naximized in the distribution which maxi-
nizes total income; hence, in the *RN* game,
otal income is (in general) greater than in
he maximin income distribution. The dif-
'erence between society's income in the two
:ases can be viewed as the insurance pre-
nium which members of the *ERA* society
›ay to protect themselves against the luck of
he draw.

If, in the *RN* game, we make expected
›tility the maximand instead of expected in-
:ome, the core corresponds to John
Harsanyi's prescription for justice. There are
hus two analytic distinctions between
Harsanyi and Rawls: one, concerning the
naximand; two, concerning the proper as-
›umption on risk averseness of agents.

We could have defined the *ERA* game in a
different way. Suppose agents wish to choose
the distribution which maximizes their ex-
›ected income, under the constraint that the
distribution assigns every agent an income of
at least Y_{min}. This specification clearly gives
rise to the maximin distribution. We have
seen that the core of the *RN* game is the
distribution which maximizes expected income, subject to no constraint on the lower bound of income received by individuals. There is a natural intermediate case between these two. Let Y_0 be a value of income which is less than Y_{min} but more than the coalition of the worst off receives in the *RN* distribution. Suppose agents wish to choose a distribution which maximizes expected income subject to the constraint that each receives at least Y_0. A distribution fulfilling this requirement exists. These distributions reflect an intermediate type of risk aversion between the *ERA* and *RN* cases.

We can thus imagine a continuum of justice games. The *ERA* game with its core of the maximin distribution is at one extreme; the *RN* game with its core consisting of the maximal total income distribution is at the other extreme. Each of the games in this continuum can be thought of as one whose core describes the social contract for a society with some degree of risk aversion, going from totally risk averse to risk neutral. Under reasonable assumptions on preferences, total income increases as we proceed along this continuum of games to the *RN* game, reflecting the decreased insurance premium society pays as it sheds its aversion to risk.

IV. Quantitative Formulations

In this section we provide a more precise notion of the nature of the maximin income distribution. We make the standard microeconomic assumption that each agent α has a preference relation on all possible combinations (l, y) of labor l and income y. We normalize labor to take values between 0 and 1 (per day). The possible work-income combinations fill the half-infinite rectangle $\{(l, y): 0 \leqslant l \leqslant 1,\ 0 \leqslant y < \infty\}$. We make the plausible assumption that the amount of additional labor an additional dollar of income will elicit decreases with total income and with total time worked. We also assume preferences are smooth. Then the indifference curves of the preference relation are convex, and slope upward and to the right (see Figure 1), and they become steeper as one proceeds upward or to the right. We will enter-

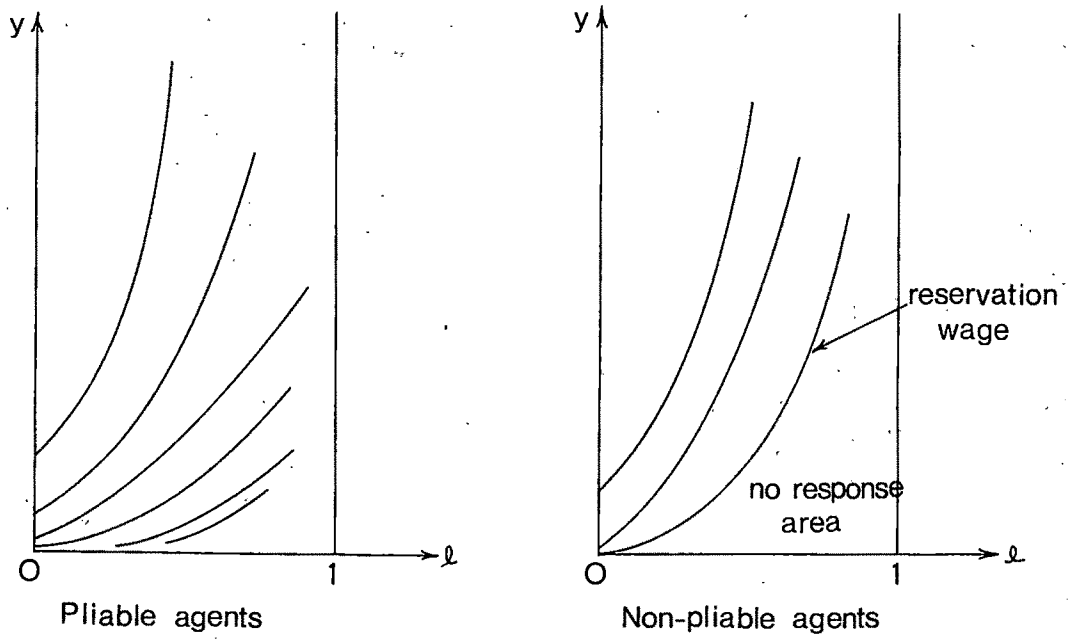

FIGURE 1

tain two alternative conceptions concerning the behavior of the indifference curves as income decreases to zero. The first, which we call the *pliability assumption,* supposes that the indifference curves through the points $(0, y)$ for $y>0$ fill up the entire half-infinite rectangle $\{(l, y)\colon 0\leqslant l<1,\ 0<y<\infty\}$. Under this assumption, any pair (l, y), with $l<1$ but arbitrarily close to 1, and $y>0$ but arbitrarily small, is preferred to no work and no income. Speaking colorfully, one might say the agents will do anything to avoid starvation, whence the adjective "pliable."

The second alternative is that the indifference curve through (0,0) is a nontrivial upward-sloping curve, so that there are pairs (l, y) in the bottom right corner of the labor-income rectangle such that the offer of income y for labor l will elicit no response at all, the alternative of no work and no income being strictly preferred. In this alternative, the indifference curve through (0,0) will be called the *reservation wage* curve. The general shape of the indifference curves under these two assumptions is illustrated in Figure 1.

Now turn to the problem of constructing a redistributive tax scheme $\tau(\alpha, y)$ to achieve the maximin income distribution. If agent α works l units of time, the social value of what he produces is $l\omega(\alpha)$, where $\omega(\alpha)$ is his "natural wage rate." If he were not taxed, his income would be $y=l\omega(\alpha)$. However, if he is taxed according to the scheme $\tau(\alpha, y)$, his income net of taxes will be

$$(1)\quad y_0(\alpha, l) = l\omega(\alpha)-\tau(\alpha, l\omega(\alpha)).$$

Thus from the point of view of the agent, his natural wage and society's tax laws combine to give him an effective wage schedule $y_0(\alpha, l)$. Clearly, too, assuming the wage rates $\omega(\alpha)$ to be given, it is equivalent to specify a wage schedule $y_0(\alpha, l)$ for each agent, or a tax schedule. The two are related to one another by equation (1).

Offered a wage schedule $y_0(\alpha, l)$, agent α chooses how much to work by the classical method of maximizing his utility subject to having the specified wage schedule. Graphically, we see by the usual considerations that his wage schedule will be tangent to the

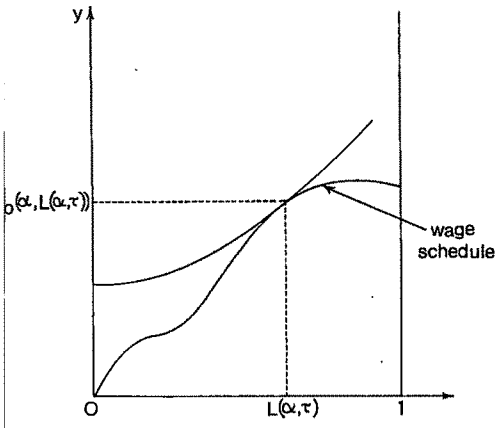

FIGURE 2

ndifference curve through his chosen labor-ncome pair $(L(\alpha, \tau), y_0(\alpha, L(\alpha, \tau)))$. See Figure 2.

Suppose to begin with that we are in the deal situation in which society is omniscient, n that it knows the natural wage rates and preference relations of all agents, and omnipotent, in that it is mandated to enact completely arbitrary tax schedules to achieve he Rawlsian maximin prescription. In this ase it can exact essentially arbitrary behav-or from its members if the pliability assump-ion holds; in general, it can force agent α to hoose any labor, income pair (l_1, y_1) above is reservation wage curve. To do this, it eed merely engineer the tax schedule of gent α so that his wage schedule $y_0(\alpha, l)$ tays always below the indifference curve hrough (l_1, y_1), except for touching it at the oint (l_1, y_1) itself. There will be many wage chedules which accomplish this. The sim-lest one simply pays nothing for $l<l_1$ and ays y_1 for $l \geqslant l_1$. This is discontinuous, of ourse. Continuous wage schedules accom-lishing the same thing can also usually be onstructed. The situation is illustrated in Figure 3.

This being so, we see that under the plia-ility assumption society can enforce strict quality of labor and income for all agents, t an arbitrary level of labor (short, perhaps, f a full day) and come as close as desired to naximizing total income at the same time. The recipe for doing this is straightforward.

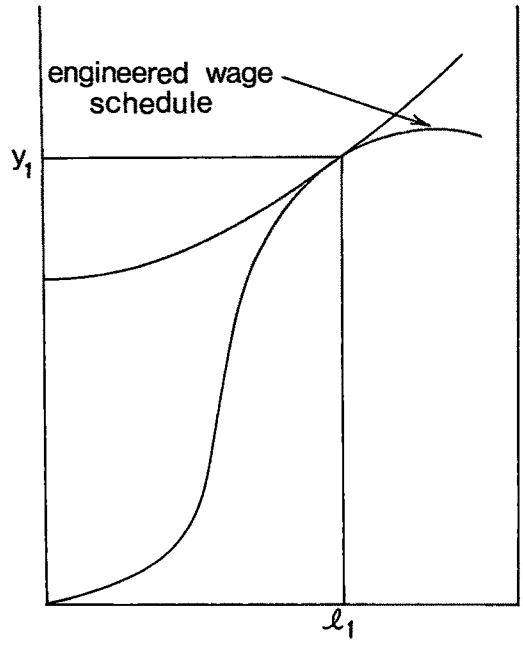

FIGURE 3

First, a desired level of work L is chosen. Then the total income to society if everyone works amount L each day is computed, and the associated per capita income Y is also computed. Then each agent is assigned a wage schedule which will lead him to choose to work L hours for income Y. Clearly this produces maximum income subject to having no one work longer than L, and since income is completely evenly distributed, the income Y will clearly be maximin subject to the labor restriction.

Thus, except for the auxiliary labor restriction, this is the ideal Rawlsian solution. To be uncomprisingly Rawlsian we should also take L as large as possible, for example, 1. There might be technical difficulties in achieving this goal, though it can be approached as closely as desired. However it is a little shocking to have begun with the goal of making everyone as well off as possible, to have been given carte blanche to accomplish the goal, and discover the result is that everyone is working constantly.

This counterintuitive feature of the solution is partially attributable to the pliability of the agents (as well as to our choice of

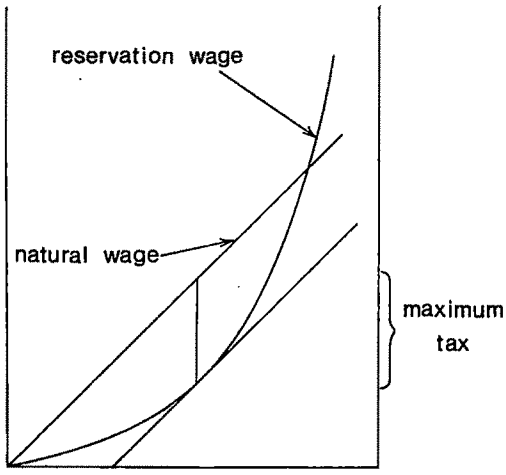

FIGURE 4

income as maximand, and our linear wage schedule (see remark (f) below)). Hence let us reconsider the problem when the agents have nonzero reservation wage curves $y_{min}(\alpha, l)$. Then if society wants agent α to work l hours, it must pay him at least $y_{min}(\alpha, l)$. This puts limits on society's powers of taxation. For in labor time l, agent α will earn $l\omega(\alpha)$, and must be paid at least $y_{min}(\alpha, l)$ to induce him to work. Thus agent α can be taxed at most the difference $l\omega(\alpha) - y_{min}(\alpha, l)$. Graphically, we see the maximum tax schedule is the gap between the reservation wage curve and the natural wage line. In particular, the maximal tax revenue to be gotten from agent α occurs at the point where the reservation wage curve is parallel to the natural wage line. See Figure 4.

Suppose now society wants to find the maximin tax scheme. It can proceed as follows. Suppose Y_0 is the maximin income, and consider agent α facing the tax scheme that produces it. First, note that the labor-income pair $(l(\alpha), Y_0(\alpha, l(\alpha))$ will be on α's reservation wage curve. For if it were not, another tax scheme could be devised which would induce α to work more for the same money. The extra income thus produced could then be distributed equally, increasing everyone's income. Next suppose α were making more than Y_0. Then α must be at the point where he is being taxed maximally. For otherwise his income and labor could be reduced by redesigning his tax schedule to move him closer to the point of maximum taxability The extra tax revenue produced could the be distributed to those with the minimur income to raise their income above Y_0.

To summarize, at the maximin situatior society will be divided in two groups: on group will be earning the maximin incom Y_0, and will be working as hard as they ar willing to for that income; the second grou will be earning more than Y_0 and will b producing the maximum possible tax reve nue to subsidize the first group. The actua maximin income Y_0 is determined by th condition that the tax revenue available fror the second group exactly balances subsidie required by the first group. Of course, ther may be people within the first group who ar being taxed positively but not maximally and the second group may be empty. Th three possibilities for an agent in this setu are illustrated in Figure 5.

Some pertinent features of this solutio should be remarked on.

(a) There is a large pool of people re ceiving the maximin wage Y_0; this pool ma be the whole society but may not. At an rate, it will be of positive measure.

(b) The possibility that the worst-of pool is not the whole society shows that eve when given arbitrary powers of taxatior society cannot force complete equality amon nonpliable agents, but must take agents incentives into account in order to produc the optimal solution. Thus even in this ex treme case, the Rawlsian incentive problen has force. This is to be contrasted with remark of Kenneth Arrow.[5] We note, how ever, that Arrow's remark is verified unde the pliability assumption.

(c) The agents making more than Y_0 ar being taxed at a zero *marginal* tax rate, in th

[5]That is, even if the center uses all the informatio on preferences and skills, it cannot entirely eliminat incentive problems, in the case of nonpliable prefer ences. We therefore disagree with Arrow, who writes, i a paper on Rawlsian justice: "If each individual revealec his productivity (the amount he could produce per uni of time), it would be possible to achieve a perfec reconciliation of justice and incentives; namely, tax eacl individual according to his ability, not according to hi actual output. Then he could not escape taxes by workin less, and so the tax system would have no advers incentive effects"(p. 260).

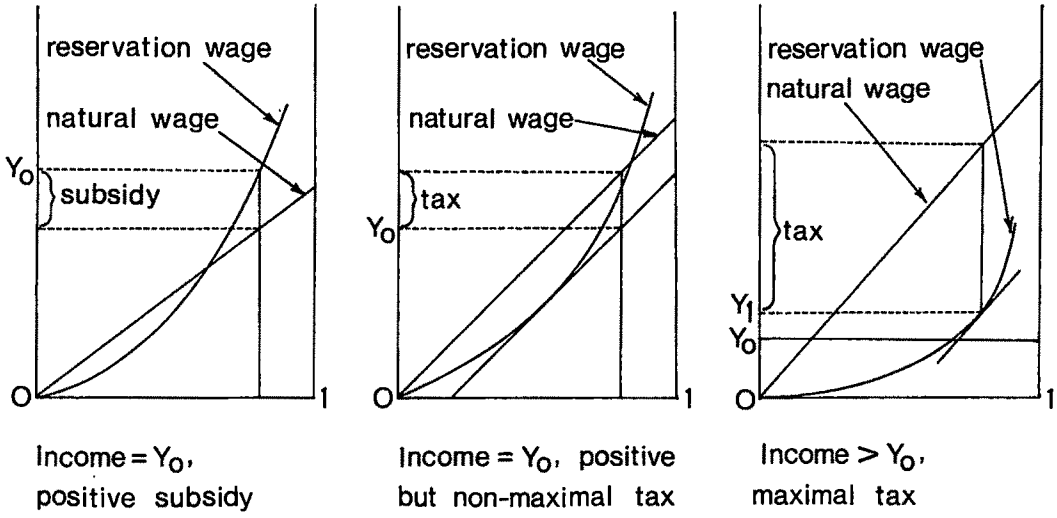

FIGURE 5

sense that if they are moved a small distance along their reservation wage curve, their tax is stationary to the first order. This is because at the optimal solution they are providing the *maximum* tax revenue of which they are capable. This state of being at zero marginal tax rate is analogous to one of the standard results of optimal taxation theory (see J. K. Seade).

(d) As a consequence of (c), we see that when the Y_0 income pool is not all of society, the maximin income tax scheme never maximizes total income. For then a first-order positive increment in the incomes of those making more than Y_0 will produce only a second-order decrease in the tax revenues they provide, hence only a second-order decrease in the incomes of the Y_0 pool. Thus total income will increase if the rich are taxed less. Hence also in the nonpliable situation there is an incompatibility between the goals of maximizing minimum income and maximizing total income. In other words, the (*ERA*) and (*RN*) games of Sections II and III are distinct in this model. We refer again to Arrow's remark.

(e) Although the strange feature, that people get no rest in the maximin solution under the pliability assumption, is, at least in general, eliminated by positing nonzero reservation wages, we have seen several pleasant features of the pliable case also vanish. Furthermore, a new pathology appears. For one of our conclusions was that everyone is working on his reservation wage curve. One might take the liberty of saying he is no happier than if he were lying in bed and starving. This is not merely a disappointment to the reformist; this feature of the solution has the mathematical consequence of making the solution unstable. For at any moment, some segment of society might decide to stop working and opt for (0,0) instead, thus upsetting the delicate balance and ruining the whole solution. Finally, the solution is clearly not Pareto optimal from the point of view of utility. For if each agent who is subsidized were assigned half his subsidy as income and not required to work at all while everyone who is taxed positively were required to work the same amount but taxed only half as much, society's accounts would again balance and everyone would be happier, though some would be much poorer.

(f) A further alternative to the above models would be to make an agent's "natural wage" curve a concave function, with a maximum achieved short of a full day. This device would also eliminate the extreme counterintuitive feature of the model with pliable agents. With nonpliable agents, the analysis would be essentially the same.

In view of the difficulties with the above models, one might want to back off from the "ideal" solution treated so far and consider

weakening society's taxing power.[6] This could be done in many ways; we can discuss only a few possibilities. The most common tax scheme actually in use is the income tax. Further, the income tax has the democratic appeal that it makes no "arbitrary" distinctions between individuals, but is based solely on the obviously pertinent variable, income. Also, there is considerable sentiment that taxes should be progressive, that is, the marginal tax rate should increase with income. (This sentiment is, we note, in some conflict with optimal taxation theory.) Certainly the tax schemes used above (see Figure 2) are neither income taxes nor progressive. We will consider briefly the consequence of requiring tax schemes to be one or the other.

First, consider income taxes. Here we will only prove a result that says income taxes are not a good instrument for achieving a Rawlsian maximin.

PROPOSITION 1: *Let α and β be two agents facing an income tax. Suppose α and β have the same preferences, but $\omega(\alpha)>\omega(\beta)$. Then α will be richer and happier than β.*

Thus if society uses an income tax to redistribute income, it cannot create a large pool of people all with the same income, as we saw it could using arbitrary tax schemes, or as we will see below, if it uses only progressive, but individually tailored, tax schemes.

PROOF:

To say the tax scheme $\tau(\alpha, y)$ is an income tax is to say it is independent of α: $\tau(\alpha, y)=\tau(y)$. Thus the wage schedule of individual α is simply $y_0(\alpha, l)=l\omega(\alpha)-\tau(l\omega(\alpha))$. Hence the wage schedule of agent α is obtained from the wage schedule of agent β by compressing the labor axis by a factor $\omega(\beta)/\omega(\alpha)$. See Figure 6.

Suppose, facing the wage schedule $y_0(\beta, l)$, agent β optimizes at a point (l_β, y_β). Then the slope of the indifference curve through

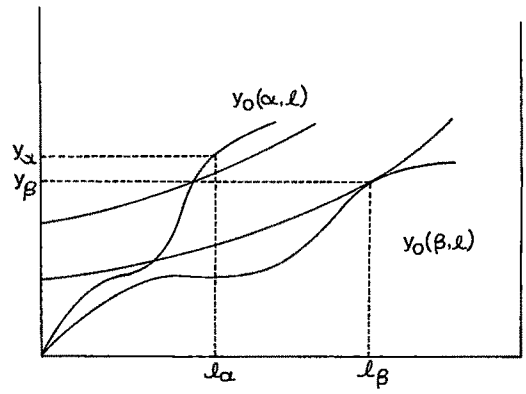

FIGURE 6

(l_β, y_β) equals the derivative $(d/dl)y_0(\beta, l_\beta)$. The wage schedule $y_0(\alpha, l)$ of α passes through the point $((\omega(\beta)/\omega(\alpha))l_\beta, y_\beta)=(l', y_\beta)$. At that point, its slope is $\omega(\alpha)[d/dly_0(\beta, l_\beta)]/\omega(\beta)$. On the other hand, the indifference curve through (l', y_β) has slope less than the indifference curve through (l_β, y_β). Hence at point (l', y_β) the curve $y_0(\alpha, l)$ passes upward through the indifference curve through that point. Hence the optimal point for α will be above the income level y_β, and will be preferred to (l', y_β) which is preferred to (l_β, y_β). This proves the proposition.

We now turn to a second possible subclass of feasible tax schemes P: those which may be tailored to individuals but must be progressive for each individual. By progressive we mean that the marginal tax rate is always increasing. From formula (1), we see this means the marginal wage is always decreasing, so that an agent's wage schedule $y_0(\alpha, l)$ is concave. We first observe that the maximin tax schedule from among this class will have a particularly simple form.

PROPOSITION 2. *The maximin progressive tax scheme will have a constant marginal tax rate for each individual. Hence his wage schedule is linear: $y_0(\alpha, l)=\tilde{\omega}(\alpha)l$.*

Remark: This result has the attractive corollary that the P-maximin tax scheme can be imposed with minimal obtrusiveness; for,

[6]That is, we may wish to limit the universe of tax schemes from which a maximin scheme is chosen to some proper subclass of all feasible schemes.

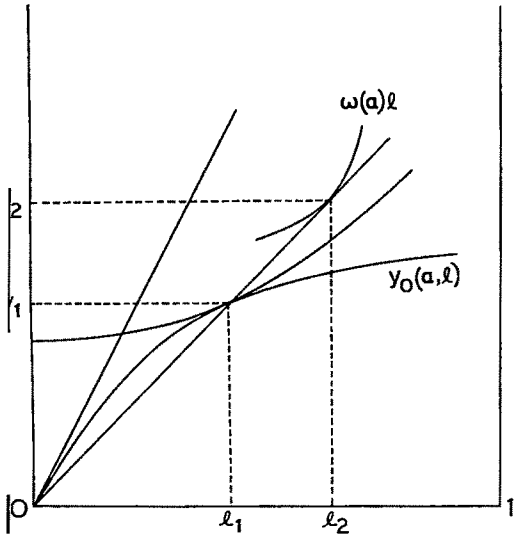

FIGURE 7

from an agent's viewpoint, he is not facing a complicated, engineered, manipulative tax scheme, but is simply receiving some net post-tax wage $\tilde{\omega}(\alpha)$ for his work. He need not even know whether this wage is greater or less than his natural wage $\tilde{\omega}(\alpha)$. Thus these linear tax schemes are easy to administer and excite the least possible amount of dissatisfaction at being taxed.

PROOF:

This result is clear from Figure 7.

Suppose agent α faces the concave wage schedule $y_0(\alpha, l)$ (i.e., a progressive tax scheme), and he optimizes at the point (l_1, y_1). The indifference curve through (l_1, y_1) is then tangent to $y_0(\alpha, l)$ at (l_1, y_1). Consider the linear wage schedule passing through (l_1, y_1). At the point(l_1, y_1), it has a larger slope than $y_0(\alpha, l)$, so it cuts $y_0(\alpha, l)$ and the indifference curve.

We distinguish two cases. First suppose α is being taxed positively at (l_1, y_1) so that $\omega(\alpha)l_1 - y_1 > 0$. This is the case illustrated. Then we may replace $y_0(\alpha, l)$ by the linear wage schedule $\tilde{y}_0(\alpha, l) = (y_1/l_1)l$. As in Figure 7 one sees that α's optimum (l_2, y_2) for $\tilde{y}_0$ will occur above and to the right of (l_1, y_1). At this point, the tax revenue produced by α will be $\omega(\alpha)l_2 - (l_2/l_1)y_1 = (l_2/l_1)(\omega(\alpha)l_1 - y_1)$, a larger amount than before. Hence facing the linear tax scheme $\tilde{y}_0$, agent α is happier, works harder, is richer and produces more tax revenue than facing y_0. Hence, among all progressive tax schemes, the maximin one generates a constant effective wage for each agent.

If α is being taxed negatively at (l_1, y_1), the above analysis applies, except that α is absorbing more tax revenue than before, so society may not be able to subsidize his new position. In this case, we can specify the following alternate procedure. Instead of adopting the new schedule $\tilde{y}_0$, we consider all linear schedules with wage $\tilde{\omega}(\alpha)$ less than (y_1/l_1). As $\tilde{\omega}(\alpha)$ decreases, the point $(y_1/\tilde{\omega}(\alpha), y_1)$ where $\tilde{\omega}(\alpha)l$ crosses the y_1 income lines moves to the right. As this point moves to the right, the slope of the indifference curve through it becomes steeper. Hence, by continuity, we will find a wage $\tilde{\omega}(\alpha)$ for which the wage line $\tilde{\omega}(\alpha)l$ and the indifference curve through $(y/\tilde{\omega}(\alpha), y_1)$ are tangent. If we assign this wage, agent α will optimize at $(y_1/\tilde{\omega}(\alpha), y_1)$. Hence he will work more, earn the same, be less happy, and absorb less tax revenue. This prescription is not quite so ideal as the previous one from α's viewpoint, but it is an improvement in terms of maximin criterion. This concludes the proposition.

Given this proposition, one can be reasonably concrete about how to construct the maximin solution from the class of progressive tax schemes. Each agent α, assigned a (post-tax) wage rate $\tilde{\omega}(\alpha)$, will produce at an optimal point. As $\tilde{\omega}(\alpha)$ varies, the optimal points will fill out a curve, the agent's *production curve*. See Figure 8.

From society's point of view, the production curve tells how much agent α must be paid to work a given length of time. Hence from here on the analysis is just as in the situation of nonpliable agents facing arbitrary tax schemes, with the production curve taking the place of the reservation wage curve. Thus one finds at the maximin solution there is a pool of positive measure of agents whose income is exactly the maximin Y_0, and every agent who earns more than Y_0 is being taxed maximally. Of course the maximin here will

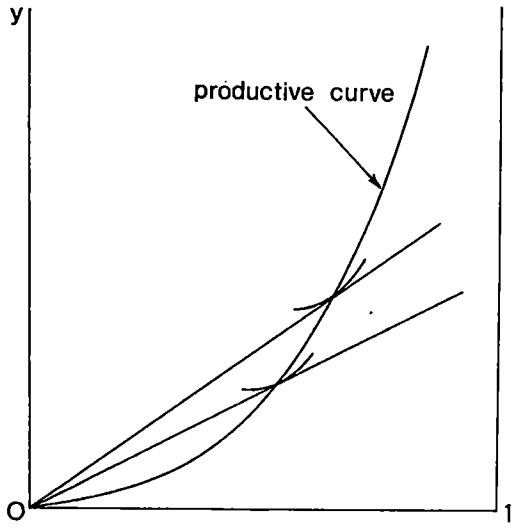

FIGURE 8

be lower than in the case of unrestricted tax schemes, but the extreme misery and consequent instability are also gone, and it is not obvious that this solution is not Pareto optimal in terms of utility. The remarks (c) and (d) concerning marginal tax rates and nonmaximization of total income carry over to this situation. This concludes our technical discussion of Rawlsian redistributive tax schemes.

V. Rawlsian Inconsistency

At this juncture an important observation about the goal of our agents must be made.[7] To produce the incentive problem, it is necessary to conceive of agents as maximizing some utility function embodying an income-leisure tradeoff.[8] Yet the maximand which agents evaluate when they decide whether or not to block an allocation is not their *utility* in the given allocation, but their *income*. This seems to be an inconsistency in the model, for if agents are maximizing utility, then is it not their utility they should evaluate in any allocation when "deciding" about withdrawal? We argue that in the Rawlsian view it is not.

To see this, recall the Rawlsian distinction between access to primary goods and utility. Income is the proxy for access to primary goods, with respect to which Rawls' ethical judgments are made. According to the blocking criterion described here, society will not accept a proposed allocation of primary goods (income), if there exists a coalition whose members could all receive more *primary goods* by taking another draw from the skill lottery themselves. To underscore the point that the maximand is an index of primary goods and not utility, we have reproduced the relevant sentences of Rawls in a previous footnote.

Indeed, we observed the sharp conflict which exists between utility and income considerations in the last section. When society assigns the maximin tax scheme, calculated from the unrestricted class of feasible schemes, everyone is miserable. In the case of nonpliable preferences (for instance), each agent is indifferent between receiving his assigned bundle of income and leisure, and starvation.

Thus: it is highly problematical to conceive of *individuals* as using the maximin primary goods criterion for themselves, when we have already relied upon their incentive behavior as produced by decisions predicated on utility as the maximand. And in our justice as the core of a game proposal, we seek to deduce just allocations as the outcome of evaluations by groups of *individuals*.

We claim, therefore, that the Rawlsian theory is inconsistent in maintaining a theory of justice which includes these three assumptions:

1) a purely contractarian approach;
2) incentive problems resulting from individual optimization of something other than income (that is, utility);
3) income (or primary goods) as the maximand of the social welfare function.

The contractarian assumption entails that in-

[7] We are indebted to Glenn Loury for first making us aware of this issue.

[8] If an agent's goal were to maximize income and not utility, then his pre-tax income-generating activity would be the same regardless of the tax rate: he would simply produce as much income as was physically possible to produce. This result can be achieved only in the case of pliable preferences with discriminatory tax schedules.

dividuals make social decisions; but the very incentive structure which gives rise to the ethical problem comes about because of a difference between the decision criterion which defines an individual's production behavior, and the one he employs when deciding whether to accept a social contract.

How might one defend the theory in this light? There are various approaches. One is to break with the utilitarian tradition, in this manner: while the income-producing behavior of an agent is a response to the tax rate he suffers or enjoys, his evaluation of his welfare does not take account of the total package of income and leisure he faces, but only of his income (primary goods). It may be better to rename the utility function a response function. Faced with a tax rate, an agent responds with certain income-producing and leisure activity; but his evaluation of the outcome is entirely in terms of post-tax income. This proposal is not so bizarre as it might first appear. Addictive behavior is an example of how people use different preference orderings in responding and evaluating. Experiments performed by psychologists also demonstrate the incorrectness of identifying preference with choice in the manner usually done in the utilitarian tradition.[9]

A second approach is to discard the contractarian interpretation of the theory, and to stipulate that it is not groups or individuals who are passing judgment on proposed income distributions, but rather "society." Now society cannot measure utility, but income is observable. Hence it is reasonable that society adopt income as the maximand and not utility. Furthermore, there is an arbitrariness about the preferences of individuals which perhaps should not be society's concern, while providing everyone access to primary goods is more easily acceptable as a minimal social function. We find this second rationale to be reasonable, especially considering the huge costs of actual coalition formation. The maximin-income criterion is one which is in principle operational in real society, while the maximin utility criterion is not.

Indeed, a related rationale is put forth quite often. Rawls refers to primary goods as the necessities for realization of life plans. Amartya Sen writes of the necessity to assign all people sufficient material goods to realize their basic capabilities. In the development literature, the catchword is meeting basic needs. These approaches focus on the necessity of guaranteeing all people some minimal level of income —if not Y_{min}, then some floor Y_0. (Recall the continuum of justice games in Section III.) In a world where material scarcity constrains the ability of people to realize their basic capabilities or life plans or basic needs, and in which such scarcity is sufficiently severe that an increment in the income assigned to the poorest will always increase their ability to realize basic needs (regardless of distribution), then a case can be made for maximin income, if one adopts a social welfare criterion which gives basic needs fulfillment lexicographic priority over utility.[10]

In offering these preliminary replies to the Rawlsian inconsistency, we are discarding the contractarian assumption of the theory. Society decides, on a quasi-contractarian basis, what allocations are acceptable by assigning persons preference orderings which differ from the ones they have, and carrying out the test of hypothetical blocking. The assumption of extreme risk aversion can be

[9] See, for instance, the fascinating results of Amos Tversky that show that preference and choice can only be identified as equivalent under the most tautological of definitions of these concepts.

[10] Additional advantages of using income as the maximand can be gleaned. One can construct the *ERA* game so that coalitions evaluate the utility received by their members, instead of incomes, and we arrive at the same conclusion as in Section II, that the maximin-utility distribution is the core of the *ERA* game. Rephrasing the blocking criterion of that game in terms of ordinal preferences: a coalition blocks if under a new lottery (almost every) member could end up with an income-leisure pair which he prefers to his present allocation of income and leisure. This statement demonstrates that for the test to make sense, we require a rule for interpersonal preference comparisons—that is, how can we decide if Mr. t prefers an allocation in his present incarnation to another allocation after reincarnation? If utility is the maximand in the *RN* game, the situation is still worse. Cardinal utility functions are required to maximize interpersonal expected utility.

seen to have the same standing: it is part of the "as if" preferences persons are assigned.

VI. Conclusion

Our main purpose has been to show how the concept of the core of a game can be used to display the connection between social contracts and theories of justice. We allow the characteristic function defining the game to vary, and so capture varying notions of justice or exploitation. The application to Rawlsian justice reveals an inconsistency in the Rawlsian proposal, which we believe could be most easily repaired by modifying the claim the theory makes to being contractarian. We have not defended such a modified theory, but have indicated how a defense might proceed.

The game which characterizes Rawlsian justice differs from the "utilitarian" game in two ways: in its choice of something other than utility as the maximand of the social welfare function, and in the assignment of extreme risk aversion to the agents in their role as evaluators of their welfares. We have argued that, if contractarianism is dropped, these features must be viewed as included in the "as if" preference structure which society assigns its members. The question is not the empirical one of deciding whether people are risk neutral or risk averse, but of deciding what the proper social assumption concerning their "preferences" should be. (This may or may not depend on what their risk preferences actually are.)

In a precise study of maximin tax schemes, the sharp contrast between maximin-income and maximin-utility is observed. If the taxing authority fulfills the mandate of the Rawlsian souls behind the veil of ignorance, with no constraints on use of information, everyone is very unhappy in the Rawlsian solution. (In the nonpliable case, people would as soon starve.) If, however, society limits itself to a subclass of feasible tax schemes, the results need not be quite so apalling from the utility point of view. One reason for such a limitation is the reduced informational requirement needed by the center to compute the maximin scheme if it chooses one of the subclasses studied. We noted that the maximin distribution chosen from the subclass of progressive but individualized tax schemes has the attractive property of assigning each person an effective post-tax wage per unit time worked. In several cases it was noted that the worst-off coalition (post-tax) is large: everyone who receives any subsidy is in it. This argues against the trivialization of the Rawlsian theory which some commentators have implied when they emphasize some very small group as the worst off.

We began by describing how Rawlsian justice could be characterized as the core of a game played by persons in society. Then we observed an inconsistency in the Rawlsian proposal, which was resolved by proposing that "society" makes the social welfare judgment using "as if" preferences. If, however, society has access to, and uses, all the relevant information, the contradiction between persons' utilities and the maximin distribution will be severe, given that we take income as the maximand in the maximin optimization. In the end, the practical attractiveness of the Rawlsian proposal may be due to the lack of information to which the government has access. In its effort to assign the maximin-income distribution in the Rawlsian state, it cannot reduce persons to their reservation wages because it does not know enough about them.

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Wage Bargaining and Employment

By IAN M. MCDONALD AND ROBERT M. SOLOW*

One of the perennial problems of business cycle theory has been the search for a convincing empirical description and theoretical explanation of the behavior of wage rates during fluctuations in output and employment. Even the empirical question is hardly settled, although the most recent careful study (see P. T. Geary and John Kennan) confirms the prevailing view that real-wage movements are more or less independent of the business cycle. There are really two subquestions here. The first presumes that nominal wage stickiness is the main route by which nominal disturbances have real macroeconomic effects, and asks why nominal wages should be sticky. The second focuses on real wages, and asks why fluctuations in the demand for labor should so often lead to large changes in employment and small, unsystematic, changes in the real wage.

We address only the second of these subquestions. We do so in the context of explicit bargaining over wages and employment by a trade union and a firm or group of firms, though one could hope that the results might apply loosely even where an informally organized labor pool bargains implicitly with one or more long-time employers. We do not harbor the illusion that trade unions are the only important source of wage stickiness. There are other plausible (and implausible) stories. Some, like this one, rest partially on optimizing decisions; others do not.

The impulse to this study was macroeconomic, but our focus is on a single employer and a single labor pool. Our methods, and therefore our conclusions, are entirely partial equilibrium. If the short-run mobility of labor is slight, and if fluctuations in real aggregate demand affect many sectors synchronously, then perhaps the mechanism we uncover here could be important in the business cycle context. But the work of embedding it in a complete macroeconomic model remains to be done.

We begin with a model in which the union is a simple monopolist, setting the wage rate unilaterally to maximize the expected or total utility of its members, and allowing the employer complete discretion over employment. We then consider a more complex institutional setup in which the union and the firm are supposed to bargain over both wage and employment and reach an outcome efficient for them both. (The monopoly outcome is not efficient, for the traditional reason.) There is, of course, a whole range of efficient bargains. A complete theory must single out one of them, but there is unlikely ever to be universal agreement on the right way to do so. Our approach is simply to try out several simple conventions and several formal solutions to the bargaining problem. We provide a framework within which they are all seen to bear a family resemblance to one another. Moreover, there is a certain assumption which makes all the proposed solutions share an important characteristic: the effects of a downswing or upswing in final demand on the negotiated outcome can be decomposed into two steps which reinforce each other with respect to employment and offset each other with respect to the wage. So it would not be surprising to find large fluctuations in employment and small unsystematic fluctuations in real wages during business cycles.

The key assumption is that product-market conditions are more sensitive to the business cycle than the reservation wage is. This would be the case, for instance, if (a) nonmarket opportunities including unemployment insurance benefits, which are not cyclically vulnerable, play an important role in the determination of the reservation wage, and/or (b) interemployer mobility is so limited that outside market opportunities figure only slightly in workers' calculations.

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to different degrees by aggregate fluctuations. For this reason alone—as a referee has pointed out—one might expect the relevant reservation wage, and even its average across industries, to vary systematically during business cycles. Nevertheless, to the extent that industrial and occupational mobility is limited in the time span relevant to business cycles, we believe our story retains plausibility.

The best developed analytical approach to this problem is the theory of implicit contracts (surveyed by Costas Azariadis). In that literature, a contract is a long-term agreement in the sense that the economic environment will change in an only probabilistically known way during the life of the contract. On the reasonable assumption that the firm is less risk averse than its employees, the typical outcome is that an efficient contract will be wage stabilizing and (unless special features are introduced) employment stabilizing as well. In our approach, by contrast, the wage-employment bargain is struck after economic conditions in the firm's product market and in the surrounding labor market are known. It is a short-term or one-shot contract. Risk enters only in a trivial sense: if the contract calls for a fraction of the union's homogeneous membership to be unemployed, the unlucky ones are chosen at random.

In real life, negotiated contracts are usually long term. But they do not specify employment, which typically is left to the discretion of the employer; in consequence, employment fluctuates a lot. Our reconciliation of the stylized facts, the theory of implicit contracts, and our own theory goes like this: if a series of short contracts would lead as our model suggests to wide variation in employment and fairly stable wages, then the same outcome might reasonably well be achieved by a long-term contract in which a stable wage is specified but the level of employment is chosen at will by the firm. (We do need a general restraint on employers of a sort that could be accomplished by "featherbedding" work rules.)

I. A Simple Monopoly Union

The simplest interesting noncompetitive institutional setup is that of a monopoly union which can set the wage unilaterally. The employer (or employers) then chooses the volume of employment. Most collective bargaining agreements do give the employer discretion over the volume of employment. Why this should be so is an interesting question (see Robert Hall and David Lilien). But it is a rare trade union that literally controls the wage and we take up more complicated bargaining arrangements later. The simple monopoly case has been analyzed before, of course (see, for example, Allan Cartter), and we have only a few novelties to add. We use this analysis mainly as a vehicle to introduce concepts, establish notation, and draw some diagrams.

The firm is characterized by a revenue function $R(L)$ giving sales proceeds as a function of employment. If the firm were a price taker in its product market, $R(L)$ would be simply $pF(L)$ where p is the parametric product price and $F(L)$ is the production function relating employment to output. We assume, as usual, that $R(0)=0$ and $R(L)$ is concave, with marginal revenue eventually becoming very small or even negative. Profit is then $R(L)-wL$.[1] If the firm is a profit maximizer, it is indifferent among (w, L) combinations that leave $R(L)-wL$ constant. These isoprofit curves in the (w, L) plane serve as indifference curves for the firm. The slope of an isoprofit curve through (w, L) is $dw/dL=(R'(L)-w)/L$. For any L, isoprofit curves have positive slope until w reaches $R'(L)$, then negative. For higher L, the switch occurs at a lower w, so the firm's indifference map is as shown in Figure 1. For any L, a smaller w creates a bigger profit, so lower isoprofit curves are better for the firm.

Let the union quote a wage w_1. The firm then seeks the lowest indifference curve that touches the horizontal line at height w_1. That is to say, it solves $R'(L_1)-w_1=0$: marginal

[1]Product price and wage rate are to be thought of as deflated by a general price index.

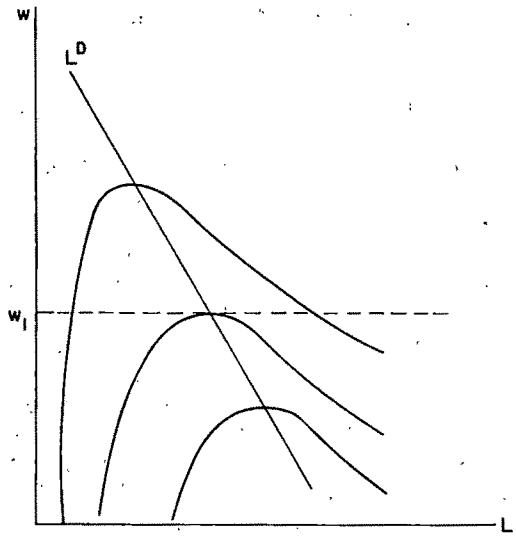

FIGURE 1

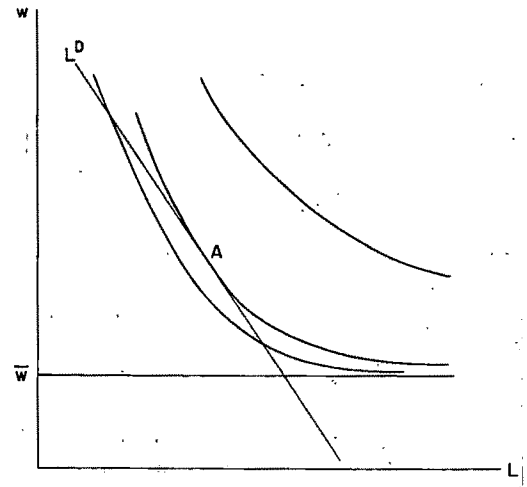

FIGURE 2

revenue product of labor equals the wage. In other words, the firm's demand curve for labor is the locus of maximum points of the indifference curves in the (w, L) plane. It is downward sloping, by virtue of the concavity of $R(L)$.

The union can achieve any point along the firm's demand curve. What is the union's objective? That is an old question in labor economics. We choose a particular answer and use it throughout. Suppose the union has N members, all alike. If L of them are employed, each member has probability L/N of having a job and achieving a level of utility $U(w)-D$ and probability $1-(L/N)$ of not being employed by the firm, where D is the fixed additive disutility of holding a job.[2] If not employed by the firm a worker achieves a level of utility $U(w_u)$, where w_u can be thought of, for short, as an unemployment compensation benefit, but should really include all the other contributions to the standard of living that would not be received if the worker were employed by the bargaining firm. $U(x)$ is the standard sort of concave utility function.

[2]We ignore—by choice—the possibility that workers are free to choose the hours and intensity of work.

The expected utility of a union member is therefore $N^{-1}\{L(U(w)-D)+(N-L)U(w_u)\}$, which can be written as $U(w_u)+N^{-1}L\{U(w)-D-U(w_u)\}$. Since w_u and N are treated as data for the purpose of union wage setting, we can set $D+U(w_u)=\bar{U}$ and summarize by saying that the union wishes to maximize $L(U(w)-\bar{U})$. The logic of this is that $L(U-\bar{U})$ is the membership's aggregate gain from employment, over and above the income w_u that every member starts with. The union's indifference map is derived from $L(U(w)-\bar{U})=\text{constant}$; the indifference curves have the usual downward-sloping convex shape in the (L, w) plane. They have the special property that they are all asymptotic to the horizontal at $w=\bar{w}$, where $\bar{w}$ is derived from $U(\bar{w})=\bar{U}$. This is shown in Figure 2.

The best wage for the union to set is determined in the obvious way by the tangency of an indifference curve with the employer's labor-demand curve as shown in Figure 2. Mathematically, this amounts to finding the maximum of $L(U(w)-\bar{U})$ with respect to L and w, subject to the constraint $R'(L)-w=0$. We can write down the first-order condition directly by equating the slope of the indifference curve through (w, L) (i.e., $-(U-\bar{U})/LU'$) to the slope of the (inverse) demand function (i.e., $R''(L)$). Since $w=R'(L)$ at any eligible point, the first-order

condition can be written as

$$(1)\quad -LR''(L)/R'(L) = \left(U(w)-\bar{U}\right)/wU'(w).$$

The left-hand side is the reciprocal of the wage elasticity of the demand for labor, taken positively; the right-hand side is the reciprocal of the elasticity of the gain from employment $(U-\bar{U})$ with respect to the wage. So the condition is that the two elasticities should be equal. (There is a second-order condition that we assume to be satisfied.)

What is the nature of wage behavior implied by this model? A change in demand conditions will affect the union's wage decision via two routes, the elasticity of demand for labor and $\bar{w}$. We consider them in order.

Solve $w=R'(L)$ to give the demand function in direct form, and insert a parameter B (for business cycle), with the convention that an increase in B increases the demand for labor at any wage. Thus the demand for labor is $L=G(w,B)$. As B rises and falls, how is the effect divided between changes in w and changes in L? Consider the first-order condition (1) written as

$$(2)\quad wG_w(w,B)/G(w,B) = wU'(w)/\left(U(w)-\bar{U}\right).$$

The cyclical sensitivity of the wage clearly depends on the extent to which changes in B affect the elasticity of demand for labor at any given wage. For instance, if the demand function shifts isoelastically—that is, the demand for labor falls in a recession, but with its elasticity unchanged at each wage—then we can always write $G(w,B)=BG(w)$, and it is obvious that (2) does not depend on B at all. In that case, the wage will be rigid during business cycles and fluctuations will fall entirely on employment. One can easily imagine cases in which the monopoly wage will move countercyclically, or procyclically for that matter, thus diminishing or magnifying the accompanying fluctuations in employment.

The other way in which the level of aggregate activity can affect the desired wage is through $\bar{w}$, which is composed of several elements. Some of these elements, such as unemployment benefits, the value of leisure, the value of working around the house, net gains from illegal activities, would appear to be affected very little, if at all, by aggregate conditions. (Unemployment benefits are sometimes raised in recession, imparting an upward effect on $\bar{w}$ and thus w.) But the other major element in $\bar{w}$ is the expected value of alternative employment opportunities and this should have a strong procyclical fluctuation through changes in the probability of finding alternative jobs and in their wages. The effect this has on the wage rate will depend on just how important a component of $\bar{w}$ it is. If job mobility is low, and/or if changes in wage rates in other jobs are small, then the effect of changes in alternative job opportunities will be slight.

We conclude this section with a canonical example. Let f be a constant elasticity of demand for labor, however generated. Take $U(w)=w^b/b$, where b is less than one, but may be negative. Then (1) yields $w/\bar{w}=(1-b/f)^{-1/b}$. Thus the monopoly wage depends negatively on the elasticity of labor demand and negatively on the risk-aversion parameter $(1-b)$. Intuitively this is how it should be. For example, if $f=\frac{1}{2}$ and $(1-b)=3$, then the monopoly wage is $(5)^{1/2}$ times the "minimum supply price" $\bar{w}$. If f is as low as $\frac{1}{4}$, $w=3\bar{w}$. If $f=\frac{1}{2}$ and $(1-b)=2, w=3\bar{w}$. If $f=\frac{1}{4}$, $(1-b)=2$ then $w=5\bar{w}$. These low values of f are in accord with econometric results. Notice that if they are combined with positive values of $(1-b)$ less than 1 the outcome is much less "realistic": thus $f=\frac{1}{2}$ and $1-b=2/3$ implies $w=27\bar{w}$.

II. Efficient Bargains

The model of wage determination just described is even more like simple product-market monopoly than it looks. The difference in appearance arises because the monopolist, in this case the union, maximizes a utility function and not profits. It is not surprising, then, that the wage-employment outcome shown at point A in Figure 2 is not efficient. There are wage-employment points at which both parties are better off. This is

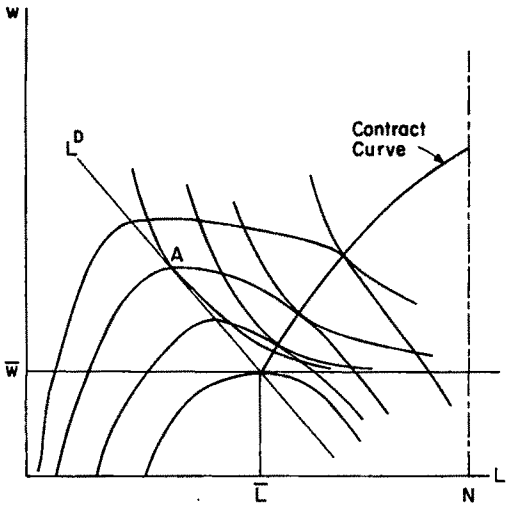

FIGURE 3

easily seen in Figure 3. The constant-profit curve passing through A is by construction horizontal at A. Therefore it cuts the downward-sloping indifference curve through A. The region to the southeast of A, between the isoprofit curve and the indifference curve, is the set of outcomes Pareto superior to A. The monopoly wage is too high and employment too low. Obviously efficient bargains are points of tangency between an isoprofit curve and an indifference curve. We call the locus of such points the contract curve; in this context that is the *mot juste*. An example is shown in Figure 3.

More complicated institutional arrangements are necessary for the achievement of efficient bargains. In particular, the union has to exercise some sort of influence over the level of employment, in contrast to the simple case where the level of employment is set unilaterally by the employer. Since the objective is to increase employment beyond the level given by the labor demand schedule, manning agreements or "featherbedding" are likely to be adopted. If it is impractical to specify the level of employment in the contract, an efficient outcome may be approximately achievable if the contract specifies the number of workers per machine, or some other similar rule, and leaves the overall aggregate to the discretion of the employer.

The contract curve is characterized by equality of the slopes of a union indifference curve and an isoprofit curve. This condition yields the equation

$$(3)\quad (U(w)-U(\bar{w}))/U'(w)=w-R'(L).$$

The first thing to notice is that the contract curve intersects the firm's labor demand curve at $w=\bar{w}$, because the right-hand side of (3) vanishes along the demand curve, and the left-hand side[3] is zero only at $\bar{w}$. The point $(\bar{w}, \bar{L})$ is actually the competitive outcome for this model. If there were no union and $\bar{U}$ were the level of utility attainable elsewhere in the economy,[4] then $\bar{w}$ would be the given supply price of labor to the employer, who would maximize profits at $\bar{L}$.

The slope of the contract curve is, by differentiation of (3),

$$dw/dL=-U'(w)R''(L)$$
$$/(U''(w)(R'(L)-w)).$$

Thus the contract curve is momentarily vertical at $(\bar{w}, \bar{L})$, and positively sloped elsewhere (because, from (3) $w \gtreqqless \bar{w}$ implies $w \gtreqqless R'(L)$).[5] No bargain can be struck with $w<\bar{w}$ so the contract curve does not extend below $\bar{w}$. If we take the total membership of the union as a given number N, then the contract curve rises to the northeast until it reaches the vertical at N, where it ends. The effective part of the contract curve might end earlier if there is an $L<N$ at which the firm's operating profit becomes small enough to induce it to shut down.

Everywhere along the contract curve, except at $(\bar{w}, \bar{L})$, the wage exceeds the marginal revenue product of employment. The firm is

[3]The expression on the left comes up frequently in the theory of contracts. If expected utility is $pU(w)+(1-p)U(\bar{w})$, then the left-hand side of (3) is the marginal rate of substitution between p and w evaluated at $p=1$ (full employment).

[4]That would be the case, for instance, if there were no unemployment compensation, but a large supply of jobs at wage $\bar{w}$.

[5]If the marginal utility of income were constant then the contract curve would be vertical, as in Hall and Lilien.

thus being induced, presumably by an all-or-none offer, to employ more workers than it would like at the agreed-upon wage. This is the insight that led to Wassily Leontief's pioneering paper. An even stronger statement is true: all along the contract curve, except at $(\bar{w}, \bar{L})$, the marginal revenue product of employment falls short of $\bar{w}$. If one thinks of $\bar{w}$ as the true supply price of labor to the employer or industry, then this is a strong reminder that the bargains along the contract curve are efficient only from the point of view of the employer and the fixed membership of the union.

To see how the contract curve is affected by changes in the economic environment, we rewrite the revenue function as $R(L, B)$, and assume that R_B and R_{LB} are both positive: prosperity increases total revenue and the marginal revenue product of labor at any level of employment. Then (3) becomes

$$(3') \quad (U(w)-U(\bar{w}))/U'(w) = w - R_L(L, B).$$

If we now differentiate (3′) with respect to B, holding L constant, we find

$$\partial w/\partial B = R_{LB}(L, B)U'(w)^2 / ((U(w)-U(\bar{w}))U''(w)) < 0,$$

and similarly

$$\partial w/\partial \bar{w} = -U'(w)U'(\bar{w}) / ((U(w)-U(\bar{w}))U''(w)) > 0.$$

Thus an increase in B (an improvement in the firm's product market) shifts the contract curve to the right. It starts at $\bar{w}$ on the new demand curve; the negotiated level of employment is higher at any wage in an efficient bargain. An increase in $\bar{w}$ (an improvement in the economy-wide alternatives open to workers) has a different effect. If the new value is $\bar{\bar{w}}$, the new contract curve begins at $(\bar{\bar{w}}, \bar{\bar{L}})$, where $\bar{\bar{L}}$ comes from the labor-demand curve. Hence the starting point of the new contract curve is shifted to the NW, and the new contract curve lies everywhere above the old one. If the external labor market improves, efficient bargains have a higher wage at any level of employment. (See Figure 4.)

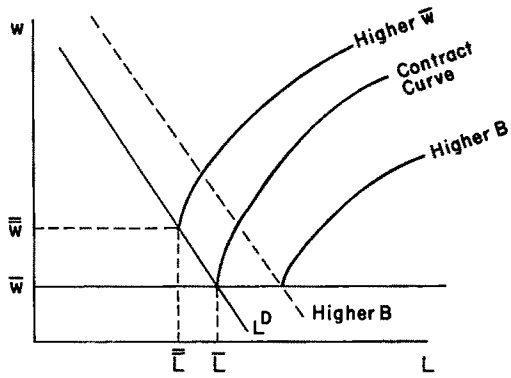

FIGURE 4

Generally speaking, simultaneous improvements in the labor market and the product market produce offsetting effects on the contract curve. Since B and $\bar{w}$ are not easily commensurable, it is hard to know how to model a generalized upswing or downswing in the economy. When we need to do so, we will tentatively assume that the B response outweighs the $\bar{w}$ response. For a "typical" labor pool, therefore, the contract curve shifts to the SE when economic conditions improve and to the NW when they deteriorate.

The contract curve probably has some approximate descriptive value. Even so, there is no generally acceptable solution concept that singles out a point on it as a likely outcome. Before we analyze some of the simpler possibilities, we digress to consider a slightly different institutional setup, as a useful conceptual exercise.

III. The Union as a Commune: A Digression

Everywhere along a positively sloped contract curve, the marginal revenue product of labor is less than $\bar{w}$, the supply price of labor. Efficiency implies starkly excessive employment. Why? The answer appears to lie in the fact that it is *ex post* more attractive to be employed than to be unemployed. To see this, let us change the rules and imagine

the union acting as a family or commune, pooling all earnings and redistributing income from its employed to its unemployed members, so that they all have equal utility. Specifically, suppose the union pays out y_e to each of its employed members and y_u to each of its unemployed members. These payments are connected by

$$U(y_u)=U(y_e)-D; \tag{4}$$

the employed worker is compensated for the disutility of work. (For any old-timers who remember the Art Young cartoon: "Me slaving over this hot stove and you working in a nice cool sewer," it is perfectly all right to think of D as negative.) The union can only pay out what its members pay in, so there is a second constraint

$$Ly_e+(N-L)y_u=Lw+(N-L)w_u; \tag{5}$$

the employed contribute the negotiated wage and the others their unemployment benefits. Since everyone is equally well off *ex post*, the aggregate utility function is simply $NU(y_u)$. Here (4) and (5) can be solved for y_e and y_u as functions of w and L, so that the collective utility function can be thought of as a function of the negotiated outcome as before.

Straightforward differentiation of (4) and (5) leads to the slope of the union's indifference curve through (w, L):

$$dw/dL=-L^{-1}[(w-w_u)-(y_e-y_u)].$$

This expression is negative because the union actually redistributes cash income from the employed to the unemployed.

The locus of tangencies between the indifference curves and the isoprofit curves defines a new contract curve. Its equation is

$$R'(L)=y_e-y_u+w_u,$$

where y_e and y_u are functions of w and L. We omit the details but record that this contract curve is *downward* sloping, passes through $(\bar{w}, \bar{L})$, and lies to the right of the demand curve for labor. The picture is thus as in Figure 5.

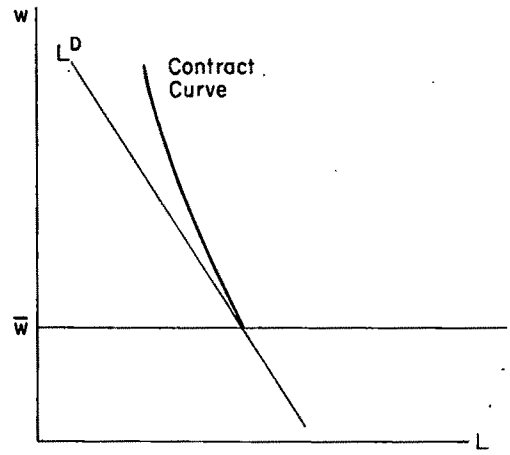

FIGURE 5

It remains true that the wage exceeds the marginal revenue product of employment in efficient bargains. The employer would prefer to reduce employment at the negotiated wage if that were permitted. But employment at a given wage is smaller in the setup of Figure 5 than it is at the same wage in the setup of Figure 3. The reason is that the *ex post* equalization of Figure 5 diminishes the incentive of the individual member to be among the employed. One important consequence is that in Figure 5 the marginal revenue product of employment exceeds the supply price of labor at every efficient bargain.

IV. Some Simple Conventions

Most formal theories of bargaining assume that the negotiated outcome will lie on the contract curve, except perhaps for the occasional conflict—a strike, say—when bargaining breaks down. We have some doubts about the empirical relevance of this assumption. But it is hard to see how one could proceed without it; so we will use it tentatively, with an eye out for its compatibility with common observation. Even so, as we have said, there is no generally accepted rule for selecting a point or other small subset of the contract curve as an especially likely candidate for the actual negotiated outcome. (The book by George de Menil contains an excellent, fairly

recent, summary of the state of the theory of wage bargaining. Models of auction markets or sealed bid procedures hardly seem to apply in this context.) In this section, we consider a few very simple conventions, any one of which might seem plausible in a specific context, but none of which has any serious claim to generality. In the next section we will take up a couple of formal bargaining models which do make such a claim. After that, we turn to conventions that might apply to the renegotiation of an original bargain when the environment changes. Throughout, we emphasize the "business cycle" implications of each solution, not its place in the theory of bargaining.

A. *A Dominant Union and "Fair Shares"*

Points to the northeast along the contract curve are successively less profitable for the employer and more favorable to the workers. A powerful union might be able to force the firm to accept zero profits, if we take zero somewhat arbitrarily as the level of profit below which the firm would leave the industry or shut down. That suggests adjoining to the equation of the contract curve (3′) the zero-profit condition $R(L, B)=wL$. Geometrically speaking, this hypothesis singles out the point at which the contract curve intersects the zero-isoprofit curve.

The hypothesis of a zero level of profits can easily be generalized and made less extreme. Suppose that history has led to the notion that there is a "fair" division of net revenue between the workers and the employer. If the normal share of wages is $100k$ percent, we can write

$$wL=k\,R(L,B). \tag{6}$$

The case of zero profits is simply $k=1$. Now (3′) and (6) are the two equations defining the negotiated wage and employment. (Except when $k=1$, (6) does not coincide with a particular isoprofit locus.)

The contract curve (3), as we know, is upward sloping in the (w, L) plane; (6), on the other hand, represents w as a fraction k of the average revenue product of labor and slopes downward by our assumptions on R. This pattern will repeat itself: the negotiated outcome is at the intersection of an upward-sloping *efficiency* locus and a downward-sloping locus that can be interpreted as reflecting *equity* (or power) considerations.

Suppose the economic environment deteriorates in a recession. If the product-market effect dominates the labor-market effect, we can concentrate on a reduction in B. The contract curve shifts to the left, as shown earlier. The locus (6) shifts down. From the crude geometry it is clear that employment must fall, but the negotiated wage can go either way. That is a promising beginning for a wage-stickiness story, so we work out the result exactly.

Differentiation of (3′) and (6) leads in the conventional way to:

$$\begin{pmatrix} z & -R_{LL} \\ L & w-kR_L \end{pmatrix}\begin{pmatrix} dw/dB \\ dL/dB \end{pmatrix}=\begin{pmatrix} R_{LB} \\ kR_B \end{pmatrix}$$

where z stands for $d/dw[w-(U(w)-U(\bar{w}))/U'(w)]=((U(w)-U(\bar{w}))U''(w))/U'(w)^2$. The determinant has sign pattern $\left(\begin{smallmatrix} - & + \\ + & + \end{smallmatrix}\right)$ and is therefore negative. Calculation, and substitution of the value of k from (6) shows that

$$sgn\, dw/dB=-sgn\{R_{LB}(1-LR_L/R)+LR_{LL}R_B/R\} \tag{7}$$

This does not depend explicitly on the utility function, except as it helps determine the point at which R is evaluated. The first term is positive and the second negative, confirming the indeterminacy of the sign of dw/dB.

Two special cases are worth noting. First of all, suppose $R(L, B)$ can be written in the form $BS(L/B)$; this gives rise to the isoelastically shifting labor-demand curve discussed earlier in connection with (2). Then $dw/dB=0$, always. So whenever the elasticity of demand for labor at the going wage is approximately invariant to the business cycle, the wage will be sticky.

The second special case puts $R(L, B)=BS(L)$; this makes the inverse demand curve for labor shift isoelastically in the business cycle so that the demand elasticity at the

going level of employment is invariant. Then dw/dB is opposite in sign to $d/dL(LR_L/R)$, which again suggests the lack of any strong directionality in the business cycle.

If it were the case that firms typically become sales constrained in recessions, so that revenue elasticity falls, the model would indicate a countercyclical rise in the wage. That seems extreme; but perhaps one might conclude that efficient bargaining will make employment, more than the wage, bear the brunt of cyclical adjustment.

We do not explore dL/dB in detail, because it is obvious from the geometry that this model makes employment strongly cyclical.

B. *A Dominant Employer*

If the union calls the tune, it is limited in its demands by the possibility that the firm will shut down. If the employer calls the tune, there is (usually) some similar limit to complete freedom of action. It may come from the possibility of a strike or other disruption, or it may come from the need of the employer to preserve a labor pool when there are opportunities for employment elsewhere in the economy. Even a dominant employer will push only so far to the SW along the contract curve. We can imagine that there is an indifference curve below which the firm will not wish to push its labor pool. There is a conceptual choice here: we could take such an indifference curve to be given by $L(U(w) - U(\bar{w}))=$constant, that is, by the *gain* to the workers from membership in the firm's labor pool. The significance of this choice is that if $\bar{w}$ falls, the firm can lower its wage at given employment to keep the workers' gain constant. On the other hand if we had fixed the limiting indifference curve by $LU(w)+(N-L)U(\bar{w}) = NU(\bar{w}) + L(U(w) - U(\bar{w}))=$ constant, the firm would have to increase its wage offer to make up for a reduction in $\bar{w}$. That seems rather too paternalistic for real life.

In this excessively paternalistic case, in fact, a simultaneous reduction in $\bar{w}$ and B must always lead to a *higher* negotiated wage along the new contract curve. Under the alternative assumption, as usual, there are forces working in both directions. The reduction in B pushes the negotiated wage upward; the contract curve shifts to the NW and so does its intersection with the unchanged limiting indifference curve. A reduction in $\bar{w}$ lowers the limiting indifference curve at given employment (more than one for one, in fact) and thus pushes the outcome to the SW. Generalized recession thus reduces the employment side of the bargain unambiguously, but the wage can go either way.

V. Formal Bargaining Theory

Most formal theories of the bargaining process proceed axiomatically. Usually one of the axioms is that the bargained outcome is efficient. But then, instead of arguing that this or that outcome on the contract curve is more "natural" than others, the bargaining theorist proposes desirable properties for a rule that would permit a referee equipped with it to go from one bargaining problem to another in some broad class, and produce a solution to each one by application of the rule. (One of the desirable properties, of course, is that the rule should always choose a point on the contract curve.) The goal of the theorist is to find a set of plausible or acceptable properties and show that there is only one rule with those properties. Raiffa argued early on that such solutions of the bargaining problem might best be thought of as Arbitration Rules; they might not have much descriptive validity in predicting the outcome of raw bargaining, but they provide a defensible handbook for an arbitrator whose job is precisely to settle a stream of bargaining conflicts. From our point of view, Raiffa's interpretation is perfectly acceptable.

Formal theories usually operate not in terms of the contract curve but in the "bargaining set" and its efficient frontier. The bargaining set is related to the contract curve in exactly the way that a production possibility set is related to the contract curve in a production box or a utility possibility set is related to the contract curve in an Edgeworth exchange box. To begin with, we need to construct the bargaining set for our model

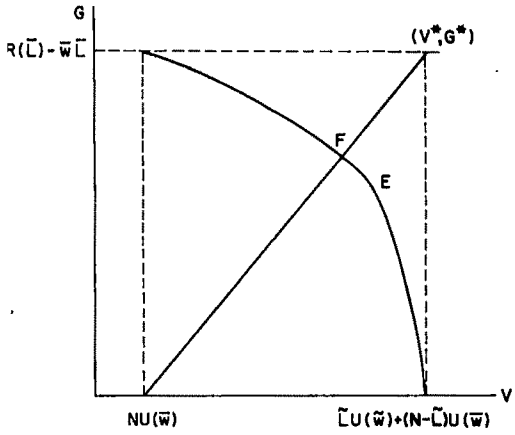

FIGURE 6

of wage bargaining. Each possible outcome (w, L) corresponds to a payoff to each party. In the case of the employer, the payoff is $G=R(L)-wL$; to the union, the payoff is $V=LU(w)+(N-L)U(\bar{w})$. The set of (G,V) swept out as (w, L) ranges over its possibilities is the bargaining set. If no bargain is struck, we take it that $G=0$[6] and $V=NU(\bar{w})$. As (w, L) traverses the contract curve, (G,V) traverses the undominated efficient subset of the bargaining set, by construction.

Axiomatic bargaining theories require that the bargaining set be convex so that, in the usual way, the efficient payoff-possibility curve is a decreasing concave function in the (G,V) plane. They justify an assumption of convexity by the possibility of randomization. That would hardly do in the wage-bargaining context, but fortunately the assumptions we have made on $R(.)$ and $U(.)$ guarantee, as tedious calculation will show, that the frontier of the bargaining set is well behaved. The picture, therefore, is as in Figure 6. (Here $\tilde{w}$ is the highest wage the employer can pay and still break even at a point on the contract curve; see Figure 3.) Selection of a point on the contract curve is equivalent to selection of a point on the efficiency locus.

The best-known formal solution to the bargaining problem is Nash's. It selects the efficient point that maximizes the *product* of the parties' gains over and above the no-contract outcome. In this case, it maximizes $G\cdot(V-NU(\bar{w}))$ or $(R(L)-wL)(U(w)-U(\bar{w}))L$ over the bargaining set. In principle, one might think of maximizing that product subject to the equation of the contract curve; but on reflection, the constraint can be omitted. Unconstrained maximization of the product by choice of (w, L) will certainly try to maximize $R(L)-wL$ for any given value of $L(U(w)-U(\bar{w}))$, so the equation of the contract curve will reappear as one of the first-order conditions of the unconstrained problem. It does. The other first-order condition turns out to imply, rather oddly,

$$w=(R/L+R'(L))/2. \tag{8}$$

At the Nash solution, the wage is equal to the arithmetic mean of the average and marginal revenue products of labor!

The Nash solution is thus defined by (3) and (8). Under our assumptions about $R(.)$, both the average and marginal revenue products are decreasing. So (8) defines a negatively sloped "equity" locus that intersects the contract curve once, at the Nash solution to the bargaining problem. Once again, we can replace R by $R(L, B)$ and ask how variation in B affects the wage coordinate of the solution. Upon calculation, it turns out that the criterion (7) holds here too, and so do the paragraphs of text immediately following (7).

One of the axioms leading to the Nash solution of the bargaining problem requires the rule to be "independent of irrelevant alternatives." Suppose that E is the solution to the bargaining problem pictured in Figure 6; now define a new bargaining problem by deleting part of the bargaining set, any part so long as the point E remains. The axiom requires that E be the solution of the new bargaining problem. Since the deleted outcomes were not chosen by the rule when they were available, they are "irrelevant" and their absence should make no difference to the outcome. This axiom has been much complained about, and justly. Intuitions about "bargaining power" and "fairness" might include the notion that if *A could* win a lot in a bargaining situation, he or she is "entitled"

[6]It would not be hard to allow for fixed costs F, so that $G=-F$ if no agreement is reached.

to more than if he or she could only, in the best of circumstances, win a little. Anyone who shares that intuition does not believe that "irrelevant" alternatives are irrelevant.

Dissatisfaction with this axiom has led to other definitions of the solution to a bargaining problem. Ehud Kalai and Meir Smorodinsky propose replacing the unsatisfactory axiom with another. Start again with Figure 6 and suppose again that E is the solution chosen by the rule. Now alter the bargaining set in the following way: leave the "best possible" outcomes for the vertical and horizontal parties unchanged, but fix things so that for each possible benefit to the horizontal party the largest possible gain to the vertical party is bigger than it was before. Then the axiom of monotonicity requires that the rule assign to this new bargaining set a solution that gives the vertical party more than at E. If the environment becomes more favorable for the vertical party in this strong sense, the vertical party must profit from the change. (Of course the environment can become more favorable for both parties; then they must both gain.)

Kalai and Smorodinsky show that replacing the axiom of irrelevance of independent alternatives with the axiom of monotonicity leads to a unique solution different from Nash's. It is easily described. Let G^* be the best that the vertical party could hope for, $R(\bar{L})-\bar{w}\bar{L}$ in Figure 6. Let V^* be the best the horizontal party could hope for. Find the point (G^*, V^*) and draw a line connecting it with the no-bargain point, whose coordinates in Figure 6 are $(0, NU(\bar{w}))$. The solution is the unique point at which that line intersects the efficiency frontier. It is shown in Figure 6 as F.

Although the geometry is simple, the arithmetic of the Kalai-Smorodinsky solution is not. The equation to be adjoined to that of the contract curve is

$$(9)\quad (R(L)-wL)/(L(U(w)-U(\bar{w})))$$
$$=(R(\tilde{L})-\tilde{w}L)/(\tilde{L}(U(\tilde{w})-U(\bar{w}))),$$

where $(\bar{w}, \bar{L})$ and $(\tilde{w}, \tilde{L})$ are the left- and right-hand end position of the contract curve. Thus $R'(\bar{L})=\bar{w}$ and $R(\tilde{L})=\tilde{w}\tilde{L}$. (We are assuming here that $\tilde{L}\leq N$; otherwise $\tilde{L}$ has to be replaced by N and $\tilde{w}$ by the wage at which the contract curve generates employment of N workers.)

The comparative statics of the solution is messy, mainly because one must keep track of changes in $\bar{w}$, $\tilde{w}$, $\bar{L}$, and $\tilde{L}$, so we hold our comments to a minimum. If we set $R(L, B)=BR(L)$ and calculate dw/dB by total differentiation, the familiar quantity $d/dL[LR'/R]=RR'/L+RR''-(R')^2$ appears; positive (negative) values are associated with $dw/dB<0(>0)$. But this time there is an additional negative term, so that even if $R(L)$ has constant elasticity, $dw/dB<0$. So the Kalai-Smorodinsky solution is more likely than the Nash solution to yield "perverse" countercyclical wage flexibility. There is not much else to be said. Even the effects of changes in $\bar{w}$ are complicated.

VI. Sales Constraints and Incremental Bargaining

This brief section serves three purposes. We make an initial stab at the potentially important case of a fix-price firm which experiences a progressively more binding sales constraint as a recession proceeds. Then we use this sketch as a vehicle to introduce another idea: that bargaining conventions may apply to the sharing of gains and losses when a change in the environment makes an initial situation untenable. The initial situation could even be arbitrary; this is an entry point for historical happenstance. Finally, the same sketch helps to clarify the underlying reason why efficient bargaining holds the potential for countercyclical movement of wage rates.

We can model a sales-constrained firm by assuming that every isoprofit curve simply ends when it reaches the value of L corresponding to maximal sales, as illustrated in Figure 7. This assumption is a bit too strong, because it ignores possible substitution among variable factors with constant output. But we shall use it for illustration.

When the firm experiences a sales constraint, the contract curve cannot extend to the right of its intersection with the vertical

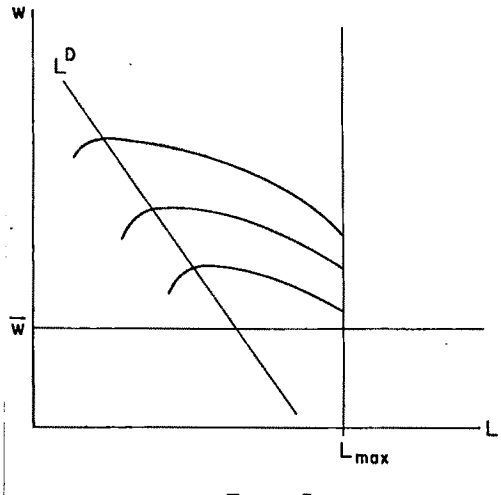

FIGURE 7

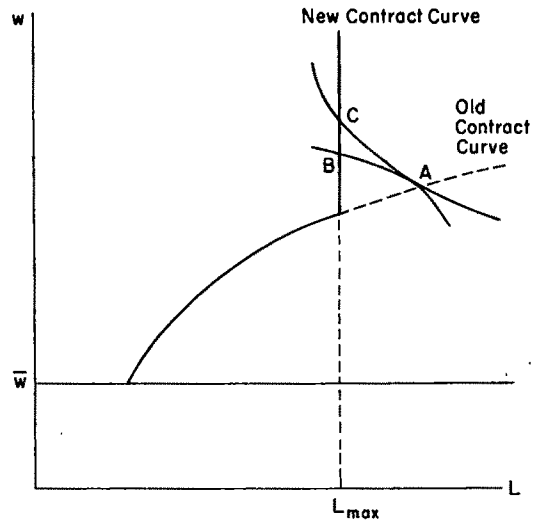

FIGURE 8

at L_{max}, because such points are inaccessible. In fact, the contract curve coincides with the vertical *above* the intersection point, as in Figure 8. (Below the intersection, points on the vertical are dominated by points on the contract curve to the left of L_{max}.)

A simple recession story might go as follows. To begin, the sales constraint is not binding and the wage-employment bargain is somewhere on the contract curve. It remains there in the early stages of the recession as L_{max} moves to the left but is not yet binding. Eventually, the constraint just binds, and then moves still further to the left. The initial bargain is no longer tenable. (We ignore labor hoarding only in order to concentrate on the logic of bargaining.) What happens now?

Given an accepted equity rule (which might also be shifting systematically as the recession proceeds) a new wage-employment bargain might be struck at the intersection of the recession-shifted equity and contract curves. But suppose the initial bargain A had arisen mostly by historical accident. It might not even be efficient. A natural incremental equity rule might be that both parties should gain, or both lose, by the change, but not one gain and the other lose. In the recession case, both must lose. This suggests that the new bargain would have $L=L_{max}$ and a wage somewhere in the interval BC between the isoprofit curve and the indifference curve associated with the initial bargain. This is shown in Figure 8.

Any point on BC has a wage higher than A; the wage would rise as employment falls. This is too sharp to be taken literally. The logic of this result provides, however, a clear insight into the mechanism through which efficient bargaining can generate countercyclical wage variation. At any point on the contract curve, the firm would prefer a lower volume of employment at the bargained wage. We have already suggested that contractual work rules and manning agreements might serve the purpose of enforcing this extra employment on the firm. A binding sales constraint thus benefits the employer by necessitating, or providing the excuse for, a reduction in employment. At the old wage, the firm would be better off and the union worse off. If the incremental equity rule forbids such an outcome, the wage must rise to transfer some of the loss from union to firm. This shows up with great clarity here because the recession is assumed to leave the revenue function unchanged except by imposing a barrier at L_{max}.

VII. Conclusion

We set out to understand why real wages might be sticky, why fluctuations in aggre-

gate demand might have their major effect on employment and little or none on the wage. Our partial-equilibrium bargaining models can hardly be expected to do that. But they do quite generally confirm a tendency for fluctuations in real product demand at the firm or industry level to be accompanied by large correlated fluctuations in employment and small changes in real wage rates that could go in either direction. What is the source of that tendency?

Geometrically speaking, it is because both our efficiency locus and our "equity" or "power" locus shifts to the left in recession and to the right in upswings, provided cyclical changes in product markets dominate those in the effective reservation wage. The shifts operate in the same direction on employment, but in opposite directions on the negotiated wage, so there is a clear possibility that the two will be statistically independent, as empirical investigation suggests.

A deeper, less mechanical, answer might go something like this. Efficient bargaining pushes the firm to hire more workers than it would like at the negotiated wage. The outcome is thus on the falling part of the isoprofit curve. The contract curve slopes upward. Higher employment and higher wages favor the workers; lower employment and lower wages favor the firm. When circumstances enforce a reduction in employment, the employer gains and the workers lose. Equity and bargaining power are likely to seek an adjustment that will transfer some of the employer's gain to the union or shift some of the union's loss back to the firm. The part of this adjustment that falls (efficiently) on wages will involve an increase in the wage. This tendency can, in principle, offset the normal cyclical deterioration of the demand for labor, in part, wholly, or not at all.

Most of the paper represents variations on this theme. If short-term contracting would lead to cyclical fluctuation in employment at a more or less stable wage, then convenience could easily lead the parties to contract for a long-term steady wage, with current employment decisions made by the firm. The union would need protection against excessive (i.e. profitable but "inefficient") reduction in the average level of employment; this could be provided by work rules or manning agreements.

Our main result is in sharp contrast to the outcome of standard models of implicit contracting with symmetric information. There, long-run contracts tend to be employment stabilizing as compared with spot-competitive labor markets. The crucial difference appears to be that implicit-contract models are closed by a utility constraint. We replace this condition by the sort of equity convention that arises naturally in the bargaining context and is less dominated by opportunities available elsewhere in the economy.

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The Decline in Aggregate Share Values: Taxation, Valuation Errors, Risk, and Profitability

By PATRIC H. HENDERSHOTT*

The past fifteen years have been disastrous or the value of common stocks in the United tates. In spite of a near doubling of the rice level, the aggregate value of publicly aded equity shares was no greater at the nd of 1977 than at the end of 1968; share alues had fallen by 40 percent relative to he replacement cost of corporate real assets.[1] ittle agreement exists regarding the cause of his collapse. Martin Feldstein (1980a) argues hat biases in the tax law impair equity val- es during inflationary periods. These biases re the use of historic-cost depreciation and rst-in/first-out (*FIFO*) inventory account- ng in computation of the corporate profits ax base and the taxation of nominal capital ains on equities. Franco Modigliani and ichard Cohn deny this and argue that an nflation-related valuation error on the part f investors is responsible for the decline in hare values. This error is the comparison of he expected *real* yield on equities with the *ominal* yield on bonds. Burton Malkiel also enies Feldstein's argument, but he attrib- tes the decline in valuation to an increase in the perceived riskiness of investment in equities vis-à-vis investment in bonds. Others might contend that a basic decline in the pre-tax profitability of the existing capital stock has occurred, although Feldstein and Malkiel appear to disagree with this contention. Eugene Fama might be identified with this position.

In both the Feldstein and Modigliani-Cohn analyses the response of the debt yield to inflation is arbitrarily set at unity. In the present study both the debt and equity yields (and thus their responses to anticipated inflation) are determined endogenously. The endogenous determination of the yield on debt is crucial to evaluation of both the Feldstein taxation and the Modigliani-Cohn valuation-error hypotheses. More specifically, both hypotheses are obviously correct if real after-tax debt yields are independent of expected inflation. That is, the overpayment of corporate taxes owing to the inflation-induced understatement of corporate depreciation and inventory costs would lower real share values, and so would the failure of investors to include inflation-induced increases in the value of corporate real capital in their calculated nominal equity returns. However, when the real after-tax debt yield declines as the underlying models imply, the real value of shares does not.

Declines in real after-tax debt yields raise actual real equity returns (shareholders gain at the expense of debtors) and lower required real equity yields, both of which tend to raise share prices. In fact, the greater is corporate taxation and the resultant tendency of share prices to fall, the greater is the decline in real after-tax debt yields and the tendency of share prices to rise. Under the assumptions that Tobin's q is unity of new marginal investments and that existing and new capital are equally productive, an increase in expected inflation will *raise* the value of exist-

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[1]The share value data are from U.S. Federal Reserve System. George von Furstenberg's (Table 1) measure of Tobin's q fell from 1.0 in 1967–68 to 0.7 at the end of 1976. Because debt has been a roughly constant one-quarter of the replacement cost of real assets, this is antamount to a 40 percent decline in the value of equities relative to the replacement cost of real assets $(1.0-0.7)/0.75$]. Feldstein (1980a) provides alternative lata supporting the 40 percent decline.

ing shares to the extent that old debt (that issued before inflation and interest rates rose) is cheaper than new debt.

If investors make the Modigliani-Cohn valuation error, then the decline in real after-tax interest rates is even sharper. In fact, nominal debt yields might not rise at all in response to increases in the expected rate of inflation. The explanation for this is straightforward. The real equity yield is roughly independent of expected inflation (the real gains at the expense of debtors offset the increased corporate tax burden). Thus, the nominal debt yield, which is tied to this real yield via the valuation error, is also roughly constant. And if the nominal debt yield is constant, share values will not decline in response to an increase in expected inflation.

Malkiel's analysis, too, depends heavily on the exogeneity of the debt yield. When this yield is fixed, an increase in the risk premium required on equities will indeed lower share values. However, when the debt yield is endogenous, most of the increase in the premium will be reflected in a lower debt yield, rather than a higher equity yield and thus lower share values. Nonetheless, consideration of the increase in the risk premium is important in that it provides an explanation for why debt yields have not risen as much as would otherwise be expected.

The decline in share values must therefore be largely attributed to other factors. Two are examined in this paper. The first is a decrease in saving, and thus corporate investment, in response to the declines in risk-adjusted real after-tax returns on debt and equity. This leads to an increase in the marginal productivity of new corporate investment and thus mitigates the decline in the equity yield. The second is a decline in the pre-tax profitability of the existing corporate capital stock. While each of these factors (and the increase in the risk premium) has apparently contributed to the decline in real share values, they explain only half of the observed decline, and most of this is due to the decline in pre-tax profitability of the existing corporate capital stock. Another factor that could explain the remainder of the decline in share values, an increase in the return on noncorporate res dential capital, is discussed but not modelle in the present paper.

The analysis of the paper proceeds as fo lows. A model of the simultaneous de termination of debt and equity yields is de veloped in Section I, and the impact of a increase in anticipated inflation on thes yields is deduced in Section II. The impact o inflation on share prices, when historic cos depreciation is required, *FIFO* accounting i employed, and nominal capital gains ar taxed, is examined in Section III. Section I is devoted to analysis of the Modigliani-Coh valuation-error model. A possible decline i profitability and increase in the required re turn on equity are evaluated in Section V a explanations of the fall in real share values

I. The Model

Two fundamental relationships are ir volved in the determination of debt an equity yields. The first is an investment equilibrium condition whereby the after-ta net return on real capital equals an averag of the real costs of debt and equity financ ing. The second is a portfolio balance condi tion in which the after-tax-adjusted return to investors on debt and equity are equated These relationships extend Feldstein's mode (1980a) by allowing for debt financing an the retention of earnings.

A. *Investment and the User Cost of Capital*

As is well known, the decision to inves depends on whether the present value of th expected revenue from investment, net o direct operating expenses and indirect taxes exceeds the supply price of capital, and o marginal investments the two will be equal Assume that inflation is expected to caus net revenues to rise at rate π (profit margin are constant) and that the productivity of th investment and thus real net revenues ar expected to decline at the output decay rat of δ per year. In the absence of taxes one ca then write:

$$(1) \qquad P_k = \sum_{t=1}^{\infty} \frac{(1+\pi-\delta)^{t-1} REV}{(1+r)^t},$$

'here P_k = current supply price of capital,
REV = current expected net revenue (operating income), and
r = financing rate (the average of interest rates on debt and equity).

ecause $\sum_{t=1}^{\infty} \frac{(1+\pi-\delta)^{t-1}}{(1+r)^t} = \frac{1}{r-\pi+\delta}$,

2) $$REV/P_k = r-\pi+\delta.$$

'he left side of equation (2) is the gross ıarginal product of capital required for a ırm to purchase a new capital good.

If one allows for the taxation of business ıcome at rate τ, for partial *FIFO* inventory ccounting, and for differences between tax nd economic depreciation and if capital oods prices are expected to rise at the same ate as general inflation raises revenues, then ıe analogue to equation (2) is

3) $$\rho = r_a - \pi + \tau v \pi + \tau(\delta - \delta^*),$$

'here ρ is the marginal product of capital et of both depreciation and taxes in a non-ıflationary world, v is the ratio of the stock f inventories based on *FIFO* accounting to he stock of fixed capital including land,[2] δ^* ; the average annual geometric rate of tax epreciation, and r_a is an average of the fter-tax debt, $(1-\tau)i$, and equity, e, rates, 'ith α being the portion of the investment hat is debt financed. Thus

4) $$r_a = \alpha(1-\tau)i + (1-\alpha)e.$$

n a noninflationary world with tax depreciaion schedules equal to economic depreciaion, $\delta^* = \delta$ and $\rho = r_a$. In an inflationary 'orld with tax depreciation schedules twice s rapid as economic depreciation, but at istoric cost, $\delta - \delta^* = \delta(2\pi - r_a)/(r_a + 2\delta)$, as hown in the Appendix.[3]

[2]Inventories were 28 percent of fixed capital and ınd at the end of 1978. With *FIFO* being employed for 0 percent of inventories, $v = 0.2$.

[3]Double declining balance depreciation was allowed ı the 1960's and tax lives were roughly 25 percent ıorter than economic lives. After 1969 only 150 percent declining balance depreciation has been allowed on structures, but in 1971 the tax service life on equipment was cut by about 15 percent. See my 1980 article with Sheng Cheng Hu, pp. 329–35.

B. *After-Tax Yields and Portfolio Equilibrium*

It is assumed that dividend and interest income are taxed at rate y and capital gains income at rate c ($c < y$). Specification of the return on equities after personal taxes thus requires an assumption regarding dividend policy. Before inflation accelerated in the second half of the 1960's, nonfinancial corporations paid out slightly less than half of their true earnings after taxes (recorded earnings with the IVA and capital consumption adjustments). In 1964 and 1965, for example, the payout ratio was 43 percent. In the 1970's, the payout ratio, so measured, jumped sharply. In 1976 and 1977, for example, the ratio was 64 percent. A plausible explanation for the higher payout is that firms view the real gains that accrue to shareholders when inflation erodes the real indebtedness of the firm as "distributable" income. To subtract interest expense based on an inflationary premium in interest rates in the calculation of earnings, but not to add the reduction in real indebtedness is inappropriate (von Furstenberg and Malkiel). When the reduction in real indebtedness, $\pi\alpha P_k K$ (where K is the real capital stock and the actual and expected inflation rates are equal), is added to true earnings to obtain distributable income, the payout ratios in 1964–65 and 1976–77 become, respectively, 41 and 43 percent.[4] A constant fraction $\gamma = 0.4$ of earnings so-calculated is assumed to be distributed as dividends.

To see precisely what is involved, it is useful to rewrite equation (4), after substitution from equation (3), as

(4′) $$e = \frac{1}{1-\alpha}\left[\rho - \alpha(1-\tau)i - \tau v \pi - \tau(\delta - \delta^*) + \alpha\pi\right] + \pi.$$

[4]These calculations are based upon $\alpha = 0.25$, $\pi = 0.012$ in 1964–65 and 0.065 in 1976–77, and the values of real assets reported in von Furstenberg (Table 1, column (2)). His data also indicate that the ratio of the market value of debt to the value of real assets remained close close to 0.25 throughout the 1952–76 period.

The first term is the expected real before-personal-tax return (inclusive of the real gains at the expense of debtors) to shareholders, γ of which is assumed to be paid out as dividends and taxed at rate y. The remainder plus π is taxed at rate c. Thus, the expected after-tax return to shareholders is

$$(5)\quad e_a=(1-y)\gamma(e-\pi)+(1-c)[(1-\gamma)(e-\pi)+\pi]=(1-y')(e-\pi)+(1-c)\pi,$$

where $y'=y\gamma+c(1-\gamma)$ is the rate at which real equity income is taxed at the personal level. A neutral tax system would tax all real equity income $(e-\pi)$ at rate $y(\gamma=1)$ and would not tax inflationary gains at all $(c=0)$. Thus the present system is biased in favor of equity returns when inflation is low and against these returns when inflation is high.[5]

The expected real after-tax return on equity equals the expected real after-tax return on bonds plus a risk premium (Feldstein and Summers, 1978):

$$(6)\quad e_a-\pi=(1-y)i-\pi+\xi,$$

where $\xi>0$ is the risk premium.

C. *Combining the Relationships*

Solving (4′) for i gives what might be labeled an investment-equilibrium (IE) relation:

$$(7)\quad i=\frac{\rho}{\alpha(1-\tau)}+\frac{1}{\alpha(1-\tau)}\times[(1-\tau v)\pi-\tau(\delta-\delta^*)]-\frac{1-\alpha}{\alpha(1-\tau)}e.$$

Substituting (5) into (6) and solving for i gives portfolio equilibrium (PE):

$$(8)\quad i=\frac{1-y'}{1-y}e+\frac{y'-c}{1-y}\pi-\frac{\xi}{1-y}.$$

These two equations can be employed t determine the impact of changes in expecte inflation on two variables.

II. The Impact of Inflation on Debt and Equity Yields

In the following analysis, ρ, α, and ξ ar assumed to be independent of π, and th impact of changes in π on debt and equit yields is determined. Later an endogenou response of ρ will be introduced. Differenti tion of (7) and (8) with respect to π allow one to obtain

$$(9)\quad \frac{di}{d\pi}=\frac{(1-y')(1+\lambda-\tau v)+(1-\alpha)(y'-c)}{\alpha(1-\tau)(1-y')+(1-\alpha)(1-y)}$$

where $\lambda=\tau d\delta^*/d\pi$ (which is negative) unle replacement-cost depreciation exists in whic case $\lambda=0$. This expression reduces to $1/(1-\tau)$ à la Feldstein (1976) or $1/(1-y)$ as i Michael Darby when

(i) $\lambda=0$ (replacement-cost depreciation a the rate of economic decay exist
(ii) $v=0$ (*FIFO* is not employed and thu no inventory profits exist)
(iii) $\gamma=1$ and thus $y'=y$ (all real earning are fully taxed)
(iv) $c=0$ (nominal capital gains are n taxed)
(v) $y=\tau$ (interest is taxed and deducted a the same rate).

Under these conditions the real after-tax deb rate, $(1-y)i-\pi$, would be invariant wit respect to π.

Alternatively, $de/d\pi$ can be solved for a

$$(10)\quad \frac{de}{d\pi}=\frac{(1-y)(1+\lambda-\tau v)-\alpha(1-\tau)(y'-c)}{\alpha(1-\tau)(1-y')+(1-\alpha)(1-y)}$$

When conditions (i)–(v) hold, this expressio

[5]For $c=y/6$ and $\gamma=0.4$, the system is biased in favor of equity returns as long as $\pi<3.0(e-\pi)$ or about 24 percent, when the real equity yield is 8 percent. For a discussion of why the concurrent equivalent capital gains tax rate would fall far short of the statutory rate, see Martin Bailey.

reduces to unity and the real after-tax equity yield, $(1-y)(e-\pi)$, would be invariant with respect to π.

A. *A Nonneutral Tax System with ρ Exogenous*

Of course, conditions (i)–(v) do not hold in the real world. Table 1 contains estimates of $di/d\pi$ and $de/d\pi$ for different values of y. The other assumed parameter values are also listed in the table. As can be seen, the hypothesized parameters yield derivatives that are well below those that would exist under a neutral tax system. To illustrate, with a neutral system and $y=\tau=0.48$, $di/d\pi=1.92$ and $de/d\pi=1.0$. The calculated values are $di/d\pi=1.31$ and $de/d\pi=0.68$ or roughly a third less. These results support Feldstein's conjecture (1976, p. 816, fn. 15) that the taxation of nominal capital gains and the use of historic-cost depreciation (and *FIFO* accounting) are a major cause of the decline in real after-tax debt yields during the last decade and a half. The results differ somewhat from those of Feldstein, Jerry Green, and Eyton Sheshinski (hereafter, F-G-S).[6]

The impact of an increase in expected inflation on nominal debt and equity yields under both a neutral tax system (as defined by conditions (i)–(v)) and the present system is illustrated in Figure 1. The negatively sloped solid schedule is the *IE* curve when the anticipated inflation rate is initially zero ($\pi^0=0$). The positively sloped solid schedule is the corresponding *PE* curve. From equations (7) and (8), respectively, the slopes of these schedules can be seen to be $-(1-\alpha)/\alpha(1-\tau)$ and $(1-y')/(1-y)$. With no expected inflation (and thus $\delta=\delta^*$), the vertical intercepts are $\rho/\alpha(1-\tau)$ and $-\xi/(1-y)$, respectively.[7] The intersection of the curves gives the initial yields of i^0 and e^0.

[6]F-G-S deduce (equation (28)) that $di/d\pi=1+\lambda/1-\tau$. With $\lambda=-0.22$ and $\tau=0.48$ the derivative is 1.50. The F-G-S result can be obtained by 1) replacing the portfolio balance equation (6) with a corporate financing cost minimization equation, namely $e=(1-\tau)i$, and 2) assuming that no firms employ *FIFO* accounting ($v=0$).

[7]Two simplifications are involved here regarding $\delta-\delta^*$. First, the intercept of the *IE* schedule is roughly $0.01/\alpha(1-\tau)$ greater because tax depreciation exceeds economic depreciation when inflation is zero owing to short economic tax lives and accelerated depreciation methods. Second, the slope of *IE* should include a second-order effect that allows for the response to δ^* to e via r_a (see the Appendix). Both of these factors are taken into account in the calculations.

TABLE 1—CALCULATED CHANGES IN DEBT AND EQUITY YIELDS IN RESPONSE TO CHANGES IN EXPECTED INFLATION

	$d\rho/d\pi=0$		$d\rho/d\pi=0.15$	
y	$di/d\pi$	$de/d\pi$	$di/d\pi$	$de/d\pi$
0.0	0.78	0.78	0.98	0.98
0.1	0.85	0.77	1.06	0.98
0.2	0.03	0.75	1.15	0.98
0.3	1.03	0.73	1.27	0.97
0.4	1.17	0.71	1.43	0.97

Notes: Underlying Assumed Parameter Values: $\gamma=0.4$, $c=y/6$, and thus $y'=y/2$; $\alpha=0.25$; $v=-0.2$; $\tau=0.48$; and $\lambda=-0.22$ when $d\rho/d\pi=0$ and -0.19 when $d\rho/d\pi=0.15$. These values are discussed in the text; fnn. 2, 4, and 5; and the Appendix (λ).

In a neutral system, an increase in π to π' would raise the *IE* schedule by $\pi'/\alpha(1-\tau)$ and the *PE* schedule by $y\pi'(1-y)$. The new dashed schedules intersect at $i'=i^0+\pi'/(1-y)$ and $e'=e^0+\pi'$, and the real after-tax rates of return are unchanged. Firms can afford to pay these higher nominal returns on the same quantities of debt and equity, and wealthholders are willing to supply the same amount of debt and equity capital as before.

The existence of historic-cost depreciation and *FIFO* inventory accounting in the face of inflation erodes some after-tax real earnings of firms by raising the effective corporate tax rate. Given ρ, firms cannot afford to pay $i^0+\pi'/(1-y)$ to debtors and $e^0+\pi'$ to shareholders. Thus the *IE* curve rises by only $[(1-\tau v)\pi'-\tau(\delta-\delta^*)]/\alpha(1-\tau)$ to the dotted schedule in Figure 1. The shift in the *PE* curve under present tax law is more complex. The taxation of nominal capital gains makes equities less attractive during an inflationary period, requiring higher relative before-tax yields on equities and thus tending to shift the dashed *PE* schedule rightward (to lower the vertical intercept). The only partial (γ)

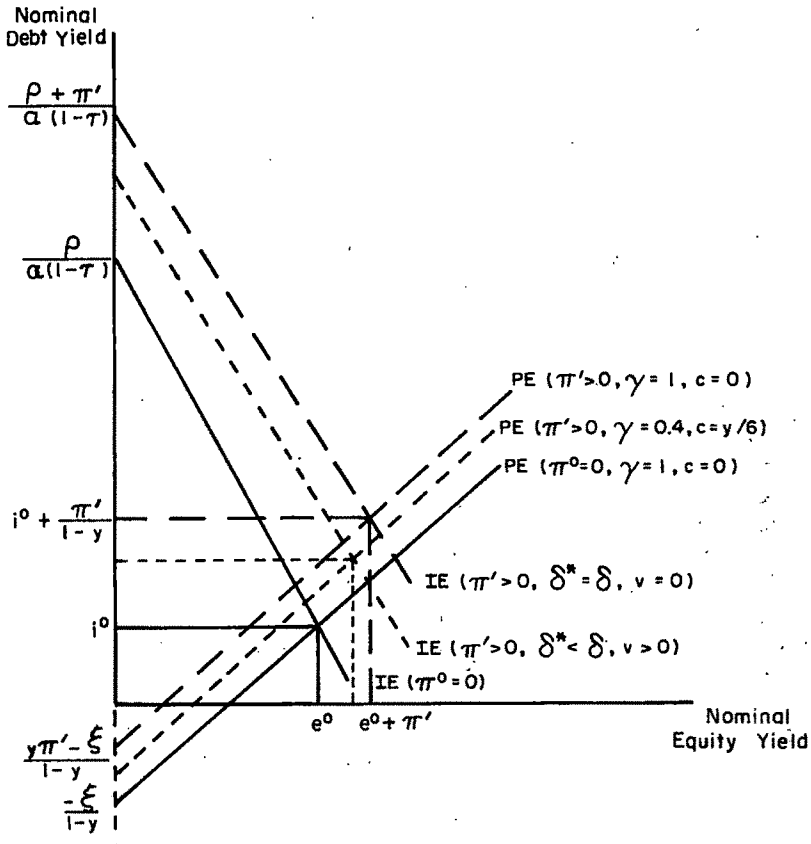

FIGURE 1. THE IMPACT OF AN INCREASE IN EXPECTED INFLATION ON DEBT AND EQUITY YIELDS UNDER BOTH NEUTRAL AND BIASED TAX SYSTEMS ($\tau=y=0.48$)

taxation of real gains, on the other hand, makes equities more attractive (with or without inflation), requiring higher relative before-tax rates. The net result of an increase in inflation is a slight bias against equities.[8] Thus current methods of taxing equity income at both the firm and personal levels act to mitigate the increase in debt yields that would otherwise occur in response to an increase in expected inflation.

B. *An Endogenous Marginal Product of Capital*

The above analysis suggests that real after-tax bond and equity yields will decline. If saving is related positively to these yields (or if the allocation of saving between equities and noncorporate capital depends on the equity yield), then corporate investment will be reduced, the marginal product of corporate capital will rise, and the decline in the real after-tax bond and equity yields will be mitigated. This would appear in Figure 1 as a rise in the dashed *IE* schedule (owing to a higher ρ).

In equilibrium, gross investment and saving per capita are equal:

$$(n+\delta)k=s(i_a^r)x, \tag{11}$$

where n is the net growth rate of capital per capita (k), $s(i_a^r)$ is the fraction of income saved as a function of the real after-tax interest rate, and x is real output per capita. With a Cobb-Douglas production function,

[8]When $\lambda=v=0$, the value of $de/d\pi$ for $y=\tau=0.48$ is $1.02>1.0$, indicating that the *PE* curve shifts rightward along the dashed *IE* schedule (the value of $di/d\pi$ is $1.80<1.92$).

:$=k^{\theta}$ and thus $k^{1-\theta}=s(i_a^r)/(n+\delta)$. The ;ross marginal product of capital (ρ^*) is then

$$\text{12a)} \qquad \rho^*=\theta k^{\theta-1}=\theta(n+\delta)/s(i_a^r)$$

ınd

$$\text{12b)} \quad \frac{d\rho^*}{d\pi}=-\frac{\rho^*}{s}\frac{\partial s}{\partial i_a^r}\frac{\partial i_a^r}{\partial \pi}$$

$$=-\frac{\rho^*\varepsilon_s}{i_a^r}\left[(1-y)\frac{\partial i}{\partial \pi}-1\right],$$

vhere ε_s is the elasticity of saving with re- ;pect to i_a^r. Reasonable parameter values are: :$_s=0.4$ and $i_a^r=0.03$ (from Michael Boskin, ɔ. 524), $(1-y)\partial i/\partial\pi=0.9$ (from Table 1 for ' in the 0.2 to 0.3 range) and $\rho^*=0.21$.[9] The ;esultant value of $d\rho/d\pi=(1-\tau)d\rho^*/d\pi$ is).15 (recall that $\rho=(1-\tau)(\rho^*-\delta)$). Thus a ;even percentage point increase in inflation vould raise ρ by a percentage point and ρ^* ɔy two percentage points.

With ρ endogenous and $d\rho/d\pi=\phi$, the ınalogues to the total derivative expressions '9) and (10) differ from the originals only in :hat $(1+\lambda-\tau v)$ in the first term in the ıumerators is replaced by $(1+\lambda+\phi-\tau v)$. These derivatives are evaluated in the two ;ight-hand columns of Table 1 for $\phi=0.15$. The endogenous ρ response raises both $di/d\pi$ ınd $de/d\pi$ by 0.2 to 0.3. For $y=0.48=\tau$, $di/d\pi$ is still 17 percent below the neutral- ;ystem value of 1.92, but $de/d\pi$ is only 3 ɔercent below its neutral-system value of ınity.

III. Inflation, Corporate Taxation, and the Market Value of Equities

The expected after-tax rate of return on existing shares, which must equal the expected rate of return on new shares, can be expressed as the dollar return on capital that shareholders can expect to earn divided by the value of existing shares, MV.[10] That is,

$$\text{(13)} \quad e_a=(1-y')\left[\hat{\rho}-\tau(\delta-\hat{\delta}^*)-\alpha(1-\tau)\hat{i}+(\alpha-\tau v)\pi\right]P_kK/MV+\frac{(1-c)(1-\alpha)\pi P_kK}{MV}$$

where "hats" on the variables denote average values pertaining to existing real capital (old and new capital are assumed to be taxed identically and financed with the same proportion of debt). Solving for $MV/P_kK=\Phi$ and replacing e_a by $(1-y)i+\xi$,

$$\text{(14)} \quad \Phi=\frac{(1-y')\left[\hat{\rho}-\tau(\delta-\hat{\delta}^*)-\alpha(1-\tau)\hat{i}+(\alpha-\tau v)\pi\right]}{(1-y)i+\xi}+\frac{(1-c)(1-\alpha)\pi}{(1-y)i+\xi}.$$

In full equilibrium, $\Phi=1-\alpha$.[11]

To deduce the impact of increases in observed and expected inflation on the value of equities relative to the replacement cost of real capital, one takes the derivative with respect to π:

$$\frac{d\Phi}{d\pi}=\frac{(1-y')\left[\tau\frac{d\hat{\delta}^*}{d\pi}-\alpha(1-\tau)\frac{\partial\hat{i}}{\partial i}\frac{di}{d\pi}+\alpha-\tau v\right]}{(1-y)i+\xi}+\frac{(1-c)(1-\alpha)-\Phi(1-y)\frac{di}{d\pi}}{(1-y)i+\xi}.$$

[9]Recall that $\rho=(1-\tau)(\rho^*-\delta)$. $\rho^*-\delta=0.11$ is consistent with Feldstein and Lawrence Summers (1977), after allowing for property taxes, and my article with Hu (1980). An average economic depreciation rate on equipment and structures of 0.10 is also consistent with these studies.

[10]The expected dollar return on new capital is simply $(1-\alpha)e_a$, where e_a is obtained by substitution for $e-\pi$ from (4′) in (5). For existing capital, average values replace marginal values.

[11]The existence of an investment tax credit at rate μ would lead to $\Phi=1-\alpha-\mu$. Because the average μ applied to all nonfinancial corporate assets is so small (see von Furstenburg, p. 360), this complication has not been incorporated in the model.

When inflation is fully anticipated, $d\hat{\delta}^*/d\pi = d\delta^*/d\pi = \lambda/\tau$. The partial $\partial\hat{i}/\partial i$ is an average "concurrent equivalent" because its value depends on the time elapsed from the change in π and it is the average change in $\hat{i}$, in present value terms, that is relevant to the current value of shares. To illustrate, in 1977 only 14 percent of net interest-bearing debt of nonfinancial corporations was short term.[12] Thus an increase in interest rates would apply initially to less than a fifth of outstanding debt (in the short run $\partial\hat{i}/\partial i < 0.2$). Over time more debt would roll over at the higher interest rate and eventually $\partial\hat{i}/\partial i$ would approach unity. In the calculations reported below, the average concurrent equivalent $\partial\hat{i}/\partial i$ is assumed to be 0.5.

With Φ initially equal to $1-\alpha$, as it was in the middle 1960s, relative share values would be independent of an increase in inflation ($d\Phi/d\pi=0$) if

$$\frac{1-y'}{1-\alpha}\left[\tau\frac{d\hat{\delta}}{d\pi}-\alpha(1-\tau)\frac{\partial\hat{i}}{\partial i}\frac{di}{d\pi}+\alpha-\tau v\right]+(1-c)-(1-y)\frac{di}{d\pi}=0.$$

But the equality holds exactly for $\partial\hat{i}/\partial i=1$ (the solution for $di/d\pi$ is identical to equation (9) because $d\delta^*/d\pi=\lambda/\tau$)! With $\partial\hat{i}/\partial i<1$, an increase in anticipated inflation raises share values owing to "cheap" outstanding debt. This result follows directly from the endogenization of the response of the interest rate to changes in expected inflation. Moreover, this result holds when ρ is endogenized. While the increase in i and thus the denominator of equation (14) is greater than that indicated in equation (9), the numerator also rises because $\hat{\rho}$ will increase with ρ.

[12]Total net interest-bearing debt is defined as credit market instruments outstanding plus trade debt less nonmonetary liquid assets and consumer and trade credit holdings. Net short-term interest-bearing debt is defined as total net interest-bearing debt less bonds and mortgages outstanding. Total net debt equalled $577.1 billion at the end of 1977 and net short-term debt was $81.7 billion; the ratio of the latter to the former was 0.138, up from 0.106 at the end of 1967. (The data are from U.S. Federal Reserve System.)

Two equations are employed to determine the effect of inflation on i and Φ when ρ is endogenous. First, the new interest rate is computed from equation (7) after three substitutions: $\tau(\delta-\delta^*)$ is replaced by $-\lambda\pi-0.01$ (the constant reflects the fact that tax depreciation exceeds economic depreciation when inflation is zero), ρ is set equal to $\rho'+\phi\pi$, and e is obtained from equation (8). The result is

$$(15)\quad i=\frac{[(1-y')(1+\lambda-\tau v+\phi)+(1-\alpha)(y'-c)]\pi}{\alpha(1-\tau)(1-y')+(1-\alpha)(1-y)}+\frac{(1-y')(\rho'+0.01)-(1-\alpha)\xi}{\alpha(1-\tau)(1-y')+(1-\alpha)(1-y)}.$$

Second, the ratio of the market value of equity to the replacement cost of real capital is calculated from equation (14), after substitution for $\tau(\delta-\delta^*)$ and $\hat{\rho}$ (which is assumed to move with ρ), using the interest rate calculated from (15).

Row (2) in Table 2 indicates the amount by which an increase in anticipated inflation from zero to 7 percent would be expected to raise the nominal interest rate and the ratio of the market value of equities to the replacement cost of real capital. The assumed parameter values common to this and all other calculations reported are listed below the table (rows (3)–(6) will be discussed later). The variables that vary (π, ξ, and $\hat{\rho}/(1-\tau)$), the nominal interest rate (i), the calculated ratio of share values to the replacement cost of real capital (Φ), and the percentage change in share prices ($\%\Delta\Phi$) are listed in the table. Row (1) indicates the value of ξ that would exist in a noninflationary world given $y=0.2$, $i=0.035$ and $\hat{\rho}/(1-\tau)=\rho^*-\delta=0.11$ (see fn. 9). Row (2) suggests that an increase in expected inflation, *ceteris paribus*, would lower relative share values by 4 percent.[13]

[13]This result is unchanged for $y=0.0$ or 0.4 (and the appropriate "noninflationary" ξ's).

TABLE 2—THE IMPACT OF AN INCREASE IN INFLATION, AND INCREASE IN THE RISK PREMIUM, AND A DECLINE IN THE PRETAX RETURN ON CAPITAL[a]

	π	ξ	$\hat{\rho}/(1-\tau)$	i	Φ	$\%\Delta\Phi$
(1)	0.00	0.0472[b]	0.11	0.0350	0.75	0
(2)	0.07	0.0472	0.1205	0.1158	0.784	+5
(3)	0.07	0.0652	0.1205	0.0970	0.775	+3
(4)	0.07	0.0652	0.075	0.0970	0.594	−21

[a] $c=y/6$, $\gamma=0.4$, and $y=0.2$; thus $y'=0.1$. Also, $\alpha=0.25$, $v=0.2$, $\tau=0.48$, $\tau(\delta-\hat{\delta}^*)=0.19\pi-0.01$, and $\hat{i}=0.035+0.5(i-0.035)$, where $0.5=\partial\hat{i}/\partial i$.

[b] Obtained by solving equation (14) assuming $\pi=0$, $i=0.035$, and $\Phi=1-\alpha=0.75$.

IV. Inflation, Valuation Errors, and the Market Value of Equities

Modigliani and Cohn have recently argued that the decline in share values is attributable to errors that investors commit in evaluating common stocks during inflationary periods. Investors are said to compare real equity returns, rather than nominal equity returns, with nominal bond yields. This is equivalent to redefining the after-tax equity yield as[14]

$$(5') \qquad e_a=(1-y')(e-\pi).$$

Substituting for e from (4′) provides an analogue to equation (13), and the combination of the latter with equation (6) results in the following expression for the ratio of the market of equities to the replacement cost of real assets:

$$(14') \quad \Phi=\frac{(1-y')\left[\hat{\rho}-\tau(\delta-\hat{\delta}^*)-\alpha(1-\tau)\hat{i}+(\alpha-\tau v)\pi\right]}{(1-y)i+\xi}$$

Next we calculate Φ for an inflation rate of 7 percent, using the values of the parameters listed in Table 2 and assuming that $di/d\pi=1.0$. The result is $\Phi=0.38$ or a 49 percent decline in share values relative to the replacement cost of assets. Thus the Modigliani-Cohn valuation error hypothesis explains the full observed fall in share values (and then some).

Closer inspection reveals the valuation-error hypothesis to be unsatisfactory (given an exogenous ρ). The above calculation was based upon $di/d\pi=1.0$, the value assumed by Modigliani and Cohn. This is the value determined when the relevant tax rate of investors is 28 percent and investors evaluate common stocks correctly, that is, as described by equations (4′), (5), and (6) when $y=0.28$ (see Table 1). However, the substitution of (5′) for (5) will yield a different value of $di/d\pi$.

The new portfolio-equilibrium relation obtained when (5′) is substituted in (6) is

$$(8') \qquad i=\frac{1-y'}{1-y}e-\frac{1-y'}{1-y}\pi-\frac{1}{1-y}\xi.$$

Differentiating (7) and (8′) and solving for $di/d\pi$,

$$(9') \quad \frac{di}{d\pi}=\frac{(1-y')(\lambda+\alpha-\tau v)}{\alpha(1-\tau)(1-y')+(1-\alpha)(1-y)}.$$

Given $\lambda=-0.22$, $\alpha=0.25$, and $\tau v=0.096$, the numerator and thus the derivative is negative. That is, an increase in the expected inflation rate would lower nominal debt yields. And if debt yields do not rise, share values will not fall.

[14] Actually, Modigliani and Cohn (p. 29) contend that investors compare the real equity return net of the real gain at the expense of debtors with the nominal bond rate. In this case, $e_a=(1-y')[e-\pi/(1-\alpha)]$. Investors would be extremely unlikely to make this further error because in Modigliani and Cohn's own analysis firms are paying out dividends based on these real earnings. Their analysis is consistent with the observed constancy of the proportion of real earnings, including those at the expense of debtors, paid out (see Part B, Section I).

The intuitive explanation for the slight decline in nominal debt yields implied by the valuation-error model is straightforward. Given a constant real return on nonfinancial capital (ρ), the real equity yield falls slightly in response to an increase in expected inflation (the real gains at the expense of debtors are more than offset by the increased tax burden owing to historic-cost depreciation and *FIFO* inventory accounting). Because it is this real equity yield to which investors are said to compare nominal debt yields, the latter also fall. In terms of Figure 1, the valuation error implies that the *PE* curve will shift down, rather than up, in response to an increase in expected inflation. The result is a sharp rise in nominal equity yields (the real yield falls marginally) and a slight decline in the nominal debt rate (the after-tax real rate falls sharply). While the former is consistent with observed data, the latter is not.

Incorporation of an endogenous response of ρ to π brings the change in the debt yield predicted by the valuation-error model more nearly into line with that experienced in the United States. With ρ endogenous, the numerator of (9′) becomes $(1-y')(\lambda+\alpha+\phi-\tau v)$. Moreover, ϕ is now a larger number because real after-tax interest rates and thus saving decline more in response to an increase in inflation and thus the marginal product of corporate capital rises more. Simultaneous solution of (12′), the modified (9′) and the expression for λ when $y=0.2$ yields $\lambda=-0.105$, $\phi=0.56$, and $di/d\pi=0.76$. Nevertheless, this response is still somewhat below the near one-for-one increase in debt yields with increases in inflation observed in the United States.[15]

Unfortunately, the problem of an unreasonable interest rate response has been replaced by an unbelievable value of ϕ. A ϕ of 0.56 implies that a seven percentage point increase in the expected inflation rate would raise ρ by four percentage points and $\rho^*-\delta$, the before-tax net marginal product by seven and one-half percentage points. This is a 68 percent increase from a value of 0.11. Any plausible elasticity of the demand for corporate capital with respect to the pre-tax net return would suggest significantly negative net corporate investment in the United States in the second half of the 1970's.

[15]The response is considerably too low if one believes that the risk premium required on equities rose in the 1970's because the major impact of such an increase is to lower debt yields (see the following section).

V. Other Causes of the Decline in the Market Value of Equities

The question still remains as to why share prices have fallen. Only two possible answers exist within the framework developed: the average pre-tax net return on capital, $\hat{\rho}$, may have declined and/or the risk premium required to induce investors to hold equities, ξ may have risen. Significant evidence exists that each of these changes has occurred; whether the changes are large enough to explain the observed decline in share values is another matter. A third answer, which is precluded by the model employed, is also considered.

A. *An Increase in ξ and Decline in $\hat{\rho}$*

Malkiel is most closely identified with the position that ξ has increased.[16] In support of his hypothesis, he computed a series on the expected return on stocks and compared it with the return on riskless long-term Treasury securities. The expected return series was an imaginative use of expected growth rates of earnings per share, obtained from the Value Line Investment Survey, for each of the companies in the Dow Jones Industrial Average. According to Malkiel's calculations, the premium rose from roughly 3.5 percent in the 1964–65 period to 6 percent in the 1975–77 period. Unfortunately, the Treasury yield series employed was the infamous average yield on all Treasury securities with maturity over ten years. Because this series contained primarily deep discount and "flower" bonds,

[16]Malkiel attributes the increase in the relative risk premium to: the recessions of 1969–70 and especially 1973–75 (after eight years of continuous prosperity), the greater variability in prices associated with a higher level of inflation, and escalating uncertain business regulation.

the quoted before-tax yield was consistently between three-fourths and one and one-half percentage points less than a new-issue equivalent yield throughout the 1968–76 period (see Timothy Cook and myself). When a new-issue equivalent Treasury yield series is substituted for the deep-discount series, the estimated premium rises by only about one and three-fourths percentage points.

There is also evidence that the pre-tax return on capital has fallen in the 1970's.[17] Feldstein and Summers (1977) compute cyclically adjusted pretax series $[\hat{\rho}/(1-\tau)]$ based on two different capital stock measures. The declines in the pretax series between 1964–65 and 1975–76 are three and two percentage points when the cyclical adjustment was based on the potential *GNP* gap as measured in 1976. Because two downward revisions in potential *GNP* have been made since then (U.S. Council of Economic Advisors, pp. 72–76), the gap in 1975–76 is now calculated to be only 70 percent of the gap employed in the Feldstein-Summer adjustment. Using the lower gap reduces the adjusted values of the series in 1975–76 by one-half to a full percentage point. This would constitute four and two and one-half percentage point declines in the two series between 1964–65 and 1975–76.

Estimates of the impact of these changes in profitability and risk on the value of shares relative to the replacement cost of real capital are given in Table 2. Row (3) shows that a 1.8 percentage point increase in the risk premium from 0.0472 to 0.0652, in conjunction with the increase in inflation to 7 percent, lowers relative share values by only 2 percent relative to the increase in inflation alone. The major impact of the increased risk premium is on the debt yield, rather than the equity yield and thus share prices (compare rows (2) and (3)). In terms of Figure 1, an increase in ξ shifts the *PE* schedule downward along a very inelastic *IE* schedule. As a result, i declines by over one and one-half percentage points, while e rises by only a third of a percentage point. The net rise in the nominal debt yield from the zero inflation value, 0.0641 $(=0.0991-0.035)$ is slightly less than the 0.07 modeled increase in inflation and is consistent with what has been observed in the United States. That is, while the increase in risk premium accounts for only a negligible part of the decline in share values, the increase does help to explain why real after-tax debt yields have declined. Row (4) indicates that a decline in the pre-tax return on existing capital from 0.11 to 0.075, in conjunction with the rise in inflation and the risk premium, reduces relative share values by 21 percent.[18] This result is not sensitive to the income tax rate employed in the analysis.

B. *Owner-Occupied Housing*

The above analysis is restricted to three assets: bonds, equities, and corporate capital. The major missing asset, both in value and in the differential manner in which it is taxed, is owner-occupied housing. The value of this housing is now close to the total value of all debt instruments (deposits and credit market instruments) held by households and nearly double the market value of equities of households. Moreover, neither the implicit rental income from housing nor the nominal capital gains on it are taxed. A case can be made that the behavior of the return on this asset has contributed to the decline in real share values.

Because of the observed decline in real after-tax interest rates and the highly leveraged financing of house purchases, the real user cost of owner-occupied housing (user

[17]The decline in the pre-tax profitability of the existing capital stock could be attributed to a number of factors. First is the sharp increase in regulatory costs. These include those generated by environmental standards, health and safety programs, and affirmative action orders. Unless the costs of these can be fully passed on to consumers, that is, labor absorbs the full costs via reduced real wages, the return on existing capital would decline. Second is the sharp rise in energy prices in the 1970's relative to that expected when the capital was put into place. This has required expenditures to render production processes more energy efficient, and the resultant processes are probably still inferior relative to those associated with new capital.

[18]Note that this is a decline in $\hat{\rho}$, not ρ, and thus that i remains at 0.0970.

cost deflated by a general price index) declined sharply between 1964 and 1978.[19] The decline is estimated to have been four and one-half percentage points for those in the 30 percent marginal tax bracket and six percentage points for those in the 45 percent bracket (see my 1981 article with Hu). Given a relatively elastic supply of housing, incremental investment in housing has promised extraordinary returns (the marginal product has exceeded the user cost). Households reduced equity purchases in order to buy housing; monthly mortgage payments replaced monthly mutual fund purchases. In effect, the required return on equity shares increased and thus real share values fell.[20] Gradual adjustment to the higher desired housing stock and the periodic increase in anticipated inflation has caused a "temporary" increase in the required return on equity and decline in real share values to last for over a decade.[21] If the expected inflation rate were to stabilize (the user cost to cease its decline) and the adjustment to the higher desired housing stock were to be completed, then the required return on equities would decline and real share values would rise.

Feldstein (1980b) has attempted to model the impact of noncorporate real assets in a framework similar to Feldstein (1980a).[22] The principal change in the model is replacement of equation (6) for household portfolio balance with

$$(6') \qquad e_a - \pi = \eta + \xi,$$

where η is a weighted average of real after-tax returns on debt and real noncorporate assets (r_a^n):

$$\eta = p[(1-y)i - \pi] + (1-p)r_a^n$$

with p being the share of nonequity household assets in debt instruments. Under the assumption that η has been constant over the last fifteen years, real share values are calculated to have declined by 24 percent.

It is noteworthy that a constant η requires an increase in the real after-tax return on noncorporate real assets. With η initially equal to 0.04, $i=0.0375$, $\pi=0.0$, and $y=0.39$ (Feldstein's values) and with $p=0.4$ (U.S. Federal Reserve System), $r_a^n=0.0514$. An increase in inflation to 0.06 (and i to 0.0975; $di/d\pi=1.0$) lowers $(1-y)i-\pi$ from 0.0229 to -0.005. For η to remain at 0.04, r_a^n must rise to 0.0670. If r_a^n were to remain constant at 0.0514, then η would decline to 0.0306 and the decline in share values would be only 8 percent (other changes in the model, such as $\partial\hat{i}/\partial i<1.0$, could eliminate the decline in share values altogether).

VI. Summary

Between the late 1960's and late 1970's, the value of common stocks in the United States fell sharply relative to the replacement cost of corporate real assets, and real after-tax debt rates declined significantly for any reasonable values of tax and expected inflation rates. Four potential causes of these declines are considered in this paper. All are related, directly or indirectly, to the observed increase in the rate of inflation. Feldstein argues that biases in the tax law reduce real share values in inflationary periods, while Modigliani and Cohn attribute the reduction to an inflation-induced valuation error of investors. The greater variability of individual prices and the increase in government regulation that accompanied the increase in inflation are also possible causes of the decline in share values. Most directly, these increases appear to have reduced the profitability of the existing corporate capital stock (as Fama's analysis suggests). At a more sophisticated level, Malkiel contends that increased uncertainty regarding future price

[19]The real user cost is approximately equal to the product of the real after-tax mortgage rate (plus some time invariant variables) and the ratio of a house price index to a general price index.

[20]Real after-tax bond yields would also tend to rise, but the above noted increase in the risk premium demanded on equities vis-à-vis bonds can explain the failure of these yields to do so.

[21]Adjustment in housing demand is particularly sluggish owing to large transactions costs and the existence of capital gains on fixed rate mortgages, gains that disappear if the mortgage is repaid. (These real gains are eroded over time via continued inflation and the amortization of the mortgage.)

[22]The later model includes debt financing and the retention of earnings, but continues to treat interest rates as exogenously determined (with $di/d\pi=1.0$) and debt as all short term ($\partial\hat{i}/\partial i=1.0$). See both J. G. Ballentine and Summers for analyses incorporating a housing sector.

and regulation changes has lowered share values by increasing the relative risk premium demanded on equity investments. Biases in the tax law, the valuation error, and the increased risk premium could also explain the decline in real after-tax debt yields, although only Feldstein has addressed this issue. The impact of each of these factors is analyzed in a model in which debt and equity yields are endogenously determined and the pre-tax return on corporate investment is treated, alternatively, as exogenous (savings is interest inelastic) or endogenous (savings is interest elastic).

We begin with an analysis of a seven percentage point increase in the observed and expected inflation rate. When the pre-tax return on corporate investment is fixed, biases in the current U.S. tax system do imply a plausible decline in real after-tax debt yields, but share values rise slightly (5 percent). With a variable pre-tax rate of return, the decline in real after-tax interest rates is mitigated. The valuation-error model explains a 50 percent decline in share values when the pre-tax return is fixed, but the decline in real after-tax debt yields is enormous. In fact, *nominal* pre-tax debt yields fall slightly. With a variable pre-tax return, the increase in interest rates is somewhat more plausible ($di/d\pi=0.76$), but the implied 68 percent increase in the required pre-tax return on corporate investment is inconsistent with the substantial positive net corporate investment observed in the past decade. To summarize, the taxation bias does not explain decline in share prices, and the valuation error model is inconsistent with observed changes in interest rates and/or the corporate capital stock.

An estimated 1.8 percentage point increase in the risk premium required on equities lowers real share values by only 2 percent, but the nominal interest rate falls by nearly two percentage points. Thus, the increase in the risk premium, in conjunction with the current method of taxing corporate income, does explain the observed decline in real after-tax debt yields. An estimated three and one-half percentage point decline in the net pretax return on capital, in combination with the increase in inflation and the risk premium, accounts for slightly over a 20 percent decline in real share values. Finally, it is conjectured that the tax treatment and financing of owner-occupied housing may also have contributed significantly to the fall in real share values.[23]

APPENDIX: HISTORIC-COST DEPRECIATION AND INFLATION

If δx_t is the rate of depreciation allowed by the tax law in period t, then the average annual geometric rate of tax depreciation is

$$\delta^*=(r_a+\delta-\pi)\sum_{t=1}^{\infty}\frac{\delta x_t}{(1+r_a)^t}.$$

If tax depreciation were equal to economic depreciation at replacement cost, then $\delta x_t=\delta(1+\pi-\delta)^{t-1}$. Substituting this term into the expression for δ^* yields $\delta^*=\delta$. However, under present law tax depreciation is based on historic cost and is accelerated at roughly twice the economic depreciation rate (see fn. 3), that is, $\delta x_t=2\delta(1-2\delta)^{t-1}$. Substituting this into the expression for δ^*,

$$\delta^*=(r_a+\delta-\pi)2\delta/(r_a+2\delta).$$

Subtraction yields the expression given in the text

$$\delta-\delta^*=\delta(2\pi-r_a)/(r_a+2\delta).$$

The λ parameter in the text is defined as $\tau d\delta^*/d\pi$. Taking the derivative of the δ^* expression and substituting $dr_a/d\pi=1+\phi-\tau v-\tau d\delta^*/d\pi$ (obtained by differentiating (3)),

$$\lambda=\frac{2\delta\tau[(\pi+\delta)(1+\phi-\tau v)-(r_a+2\delta)]}{(r_a+2\delta)^2-2\delta\tau(\pi+\delta)}.$$

With $\delta=0.10$, $r_a=0.09$, $\phi=0.0$, $\tau=0.48$, and $\pi=0.04$ (the r_a and π values are approximated average values for the 1964–78 period

[23]Roger Gordon has recently investigated some of the same issues discussed in the present paper. He, too, concludes that the impact of increases in inflation on the taxation of corporate capital is unlikely to have played a significant role in the decline in real share values.

(see my 1980 article with Hu), $\lambda = -0.22$. With ϕ changed to 0.15 (when a response of ρ to π is introduced), $\lambda = -0.19$.

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Spatial Nonlinear Pricing

By DANIEL F. SPULBER*

In location theory, discussion of spatial price policies chosen by a monopoly is usually limited to three particular pricing methods: uniform mill pricing, uniform delivered pricing, and discriminatory local pricing.[1] These price policies certainly do not exhaust the mill's pricing options. More significantly, optimally chosen pricing policies may differ considerably, yielding higher profits. The essential insight is that in a model with given transport costs, customers at varying distances from the firm face different marginal transport costs for each unit of the good purchased. Therefore, even if customers are identical in all respects other than location, their marginal willingness to pay for the good will differ. The firm may take advantage of these differences by offering a *nonlinear outlay schedule at the mill* through quantity discounts or premia and quantity bundling.[2] The nonlinear price schedule will cause the customers to "reveal" their location through the quantity purchased.

Assuming that customers differ only in terms of location, this paper presents a solution to the mill's problem of choosing an optimal nonlinear price schedule for general forms of the consumer utility function, the consumer density function, and the transport cost function when the mill has constant marginal production costs. The optimality of nonlinear pricing depends upon the assumption that consumer arbitrage possibilities are limited. This is a reasonable assumption for industries whose customers are spatially separated and find communication costly. The optimal nonlinear price schedule is shown to involve a positive markup above marginal costs which depends upon transport costs and the spatial distribution of consumers.

The mill's pricing problem when its customers are spatially dispersed is seen to be formally similar to the nonlinear pricing framework of Michael Spence, Joseph Stiglitz, Kevin Roberts, and the optimal taxation framework of James Mirrlees. The nonlinear pricing literature can be viewed as an extension of work on two-part and multipart tariffs. Ronald Coase, Walter Oi, Martin Feldstein, Yew-Kwang Ng and Mendel Weisser, Stephen Littlechild, and Bridger Mitchell study two-part tariffs of the kind used in utility and transportation pricing. Hayne Leland and Robert Meyer extend the analysis to block pricing and Gerald Faulhaber and John Panzar examine optimal two-part tariffs with self-selection. The discrimination through nonlinear pricing increases revenues for a firm which has incomplete information in the form of a distribution of consumer characteristics. The nonlinear price framework applies in a natural way to modelling the problem of a mill that knows the spatial distribution of its customers.

This paper obtains an explicit form for the nonlinear price schedule by introducing additional assumptions on consumer utility, the spatial distribution of consumers and the exogenous transport charges which are somewhat more general than standard location theory assumptions. Consumers are assumed to have quadratic utility. The spatial distribution of consumers is assumed to depend upon a parameter which allows the density of consumers to decrease, remain constant or increase with increasing distance from the mill. Finally, transport charges are assumed to include a fixed terminal charge per unit transported as well as a conveyance rate per

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[1]See, for example, Martin Beckmann (1968; 1976).

[2]The optimality of quantity-dependent mill pricing should not be confused with the work of John Greenhut and Melvin Greenhut who examine the nonlinearity of delivered prices with respect to distance from the mill.

unit per mile. Given these assumptions, the mill is shown to offer a *marginal* nonlinear price schedule composed of a *fixed per unit charge* and *positive quantity discounts*.

The market equilibrium with nonlinear mill pricing is compared to an equilibrium in which the mill practices local price discrimination. The market area under nonlinear pricing is shown to be smaller than the market area under local price discrimination. Further, the relative levels of total output and profits and consumer welfare under these pricing policies are shown to depend crucially upon the spatial distribution of consumers. In particular, profits, output, and consumer welfare under nonlinear pricing are shown to be greater than, equal to, or less than profits, output, and consumer welfare under local price discrimination depending upon whether consumer density decreases, remains constant, or increases with increasing distance from the mill. These results suggest that the mill's choice of a pricing policy will depend upon the type of market it serves. If the market is not overly dispersed, nonlinear pricing is preferable both from the profit-maximizing and welfare-maximizing points of view.

The assumption of exogenous transport charges is justified if the transport market is competitive. Many mills are, however, "held captive" by one or a few transport firms. For this reason, a variant of the model is examined with *endogenous* transport charges set by a monopolist transport firm, henceforth designated as the "railroad," which interacts strategically with the mill. By charging transport rates per ton mile, the railroad is able to perfectly price discriminate among customers by location. The railroad and the mill are assumed to play a Nash noncooperative game in pricing strategies. Existence of a noncooperative equilibrium is demonstrated and the properties of the equilibrium are examined both when the mill selects a nonlinear price schedule and when the mill practices local price discrimination. It is shown that if consumers are not overly dispersed, mill profits, output, and consumer welfare are greater at the noncooperative equilibrium with nonlinear mill pricing. This is seen to result in part from lower conveyance rates a the nonlinear price equilibrium.

Beckmann (1976) observes that eve though local price discrimination is the mos profitable of the standard pricing policies i will not be the most common one since pric discrimination is illegal and since its effectiv administration depends upon the firn supplying its own transportation. Nonlinea pricing is easily administered at the mil without the need for direct control of trans portation. On the other hand, unless it i justified by cost or competitive considera tions, nonlinear pricing is also illegal unde the Robinson-Patman Act since it dis criminates against purchasers of differen quantities of a good. However, a legal de fense based upon quantity dependent dif ferences in the costs of manufacture and sal may be more applicable in the case of non linear pricing than in the case of local pric discrimination. William Holahan demon strates that, for a spatial monopoly, spatia price discrimination results in a higher out put and greater consumer welfare tha standard mill pricing. The results obtained i this paper regarding output and consume welfare resulting from nonlinear mill pricin may constitute an argument for nonlinea pricing on efficiency grounds for markets i which consumers are not overly dispersed.

The paper is organized as follows. Sectio I presents a general nonlinear pricing mode in which customers are spatially distribute around a mill. An explicit solution with gen eralized location theory assumptions is pre sented in Section II and compared to th local price discrimination outcome in Sectio III. Strategic interaction with a railroad i considered for a Nash equilibrium in Sectio IV. Conclusions are presented in Section V.

I. Nonlinear Mill Pricing

Consider the problem of a monopolis selecting an optimal pricing policy when its customers are spatially dispersed. The monopolist sells a good $x \in R_+$ and selects an *outlay schedule* for individual customers $P(x)$. Let $p(x) \equiv dP(x)/dx$ denote the *marginal price schedule*. The selection of the marginal

rice schedule by the firm depends upon nowledge of the distribution of consumer haracteristics and the consumer's optimiza- ion procedure.

Consumers are assumed to be identical in ll respects other than location. Location is epresented by distance from the firm r. The narket area is not restricted a priori but is etermined by market prices and consumer illingness to pay.[3] Consumers are distrib- ted according to the cumulative distribution $G(r)$ where $r \in [0, \infty]$, $G(0)=0$ and $g(r) \equiv G(r)/dr$ for all r. Consumers face exoge- ous transport costs which depend upon the mount of their purchase and the distance is to be carried, $c(r, x)$ where $\partial c(r, x)/ r \equiv c_r > 0$, $\partial c(r, x)/\partial x \equiv c_x > 0$ and $^2c(r, x)/\partial r \partial c \equiv c_{rx} = c_{xr} > 0$. For ease of resentation, income effects are assumed way. The consumer purchases x and a unit- riced numeraire y. The representative con- umer's utility function is given by $U(x, y) = (x) + y$ where u is differentiable, increasing nd concave in x. The consumer at location r hooses demand $x^* = x^*(r)$ so as to maxi- nize net benefits,

$$1) \quad \max_x \left[u(x) - c(r, x) - P(x)\right].$$

he consumer's first-order necessary condi- ion is then

$$2) \quad u'(x) = c_x(r, x) + p(x).$$

his is a "self-selection condition" in the ense that a consumer at location r exhibits he net marginal willingness to pay for good , $u'(x) - c_x(r, x)$. Let $V(r)$ denote the net enefits of participating in the market for x or a consumer at distance r from the firm,

$$3) \quad V(r) = u(x^*) - c(r, x^*) - P(x^*).$$

[3]As Beckmann observes, "... as far as demand exists, t is customary to disregard the possibility that sales anish because of a vanishing population. Rather the orderline is defined by the condition that delivered rices reach the critical level, where demand falls to ero" (1976, p. 28). The analysis in the paper can be asily redone with a finite exogenous market boundary.

The consumer has the option of nonparticipation which implies the restriction $V(r) \geqslant 0$ for all r.

The monopolist is assumed to have constant marginal costs $k > 0$. The monopolist selects the marginal mill price $p(x)$ to maximize profits. The "state variable" is $V(r)$ so that $dV(r)/dr \equiv V'(r)$ represents the change in net consumer benefits at increasing distances from the mill. By the envelope theorem, employing (2), we obtain the "equation of motion,"

$$(4) \qquad V'(r) = -c_r(r, x^*).$$

Note that the outlays of a consumer at distance r can be obtained by rewriting (3),

$$(5) \quad P(x^*) = u(x^*) - c(r, x^*) - V(r).$$

Employing equations (4) and (5), and letting $\psi(r)$ denote the shadow price on the equation of motion, form the Hamiltonian,

(6)

$$H = \left[u(x^*) - c(r, x^*) - V(r) - kx^*\right] g(r) + \psi(r)\left(-c_r(r, x^*)\right).$$

The necessary conditions are

$$(7) \quad \partial H/\partial x^* = \left[u'(x^*) - c_x(r, x^*) - k\right] g(r) - \psi(r) c_{rx}(r, x^*) = 0;$$

$$(8) \quad \partial H/\partial \psi = V'(r) = -c_r(r, x^*);$$

$$(9) \quad \psi'(r) = -\partial H/\partial V = g(r);$$

$$(10) \quad \psi(0)V(0) = 0; \quad \psi(0) \geqslant 0,$$

$$\lim_{r \to +\infty} \psi(r)V(r) = 0, \quad \lim_{r \to +\infty} \psi(r) \geqslant 0.$$

Consider the transversality conditions (10).[4] Assume that those customers located

[4]Note that if the market boundary is finite and exogenous, say $r \leqslant \bar{r}$, then the endpoint transversality condition becomes $\psi(\bar{r})V(\bar{r}) = 0$, $\psi(\bar{r}) \geqslant 0$.

at the mill are able to gain by purchasing from the firm, $V(0)>0$. Therefore, $\psi(0)=0$. From the definition of integration, and equation (9),

$$(11)\quad \psi(r)=\psi(0)+\int_0^r \psi'(z)\,dz=G(r).$$

Substituting into (7) and applying the self-selection condition (2) yields the optimality equation for the monopolist's marginal price schedule,

$$(12)\quad p(x)=k+(G(r^*)/g(r^*))c_{rx}(r^*,x)$$

where $r^*=r^*(x)$ is the inverse of the optimal consumer purchase function $x^*=x^*(r)$.

The important point made by equation (12) is that there is a positive markup above marginal cost since $c_{rx}>0$. Given that r^* is the distance at which x units are purchased, *the markup on the last unit of a purchase of amount x depends upon the number of customers located within distance r^* from the mill weighted by the density of consumers located at r^*.*

II. Explicit Solution of the Model

To obtain an explicit solution for the nonlinear price schedule, we introduce particular functional forms for consumer utility, consumer density and transportation costs. Consumer utility is assumed to have the quadratic form,

$$(13)\quad u(x)=\alpha x-(1/2)\beta x^2$$

where $\alpha>0$ and $\beta>0$. The cumulative distribution of consumers is assumed to be given by $G(r)=ar^b$ where $a>0$ and $b>0$. The density of consumers decreases, remains constant, or increases as distance from the mill increases depending upon whether the dispersion parameter b is less than, equal to, or greater than one. The uniform distribution of consumers with regards to distance from the mill ($b=1$) includes the case of uniform distribution along a line of Harold Hotelling. The uniform distribution of consumers in the plane implies that consumer density increases with the square of the distance from the mill, $b=2$.

Transportation costs are assumed to b linear,

$$(14)\quad c(r,x)=(t+cr)x$$

where $t\geq 0$ is the *terminal charge* per uni transported and $c>0$ is the *conveyance rat* per unit per mile.[5] The costs of transport ar paid directly by consumers.

To solve for the optimal marginal pric schedule, rewrite the self-selection conditio (2),

$$(15)\quad \alpha-\beta x=t+cr+p(x)$$

and the optimal price equation (12),

$$(16)\quad p(x)=k+(r^*/b)c$$

where r^* solves (15). Substituting for r^* i (16) and rearranging terms yields the optima marginal price schedule,

$$(17)\quad p(x)=(1/(b+1))(bk+\alpha-t-\beta x).$$

Solving (16) and (17) for r^* yields

$$(18)\quad r^*(x)=(b/c(b+1))(\alpha-k-t-\beta x).$$

The marginal price schedule is clearly de creasing in x, $p'(x)=-\beta/(b+1)$, implyin that quantity discounts are offered by the mill The quantity discounts are an increasin function of the own-price-effect parameter β and are decreasing in the dispersion parame ter b. The marginal price on x units is a increasing function of marginal cost k, an the maximum price α and a decreasing func tion of the terminal charge t.

The distance r^* at which x units are de manded is a decreasing function of quantit demanded implying that less units ar purchased as distance from the mill in creases. Beyond a critical distance r_0^N, zer units are purchased. The critical distance r_0^N is given by

$$(19)\quad r_0^N=(b/c(b+1))(\alpha-k-t).$$

[5]Sylvester Damus discusses linear distance tariffs and tests the hypothesis of negative correlation of actual tariffs and conveyance rates.

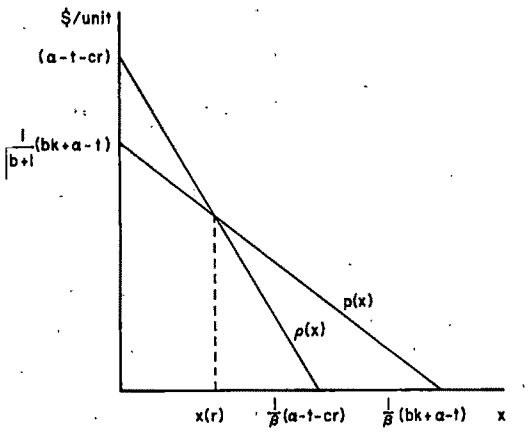

FIGURE 1. MARGINAL WILLINGNESS TO PAY: $\rho(x)$;

The critical distance is a decreasing function of the conveyance rate c, the terminal charge t, and marginal production costs k. The critical distance is an increasing function of the maximum price α and the dispersion parameter b. For the good x to be viable, assume that $\alpha>k+t$. The slope of the marginal price schedule equals $1/(1+b)$ times the slope of the consumer's marginal willingness to pay schedule $\rho(x)\equiv\alpha-t-cr-\beta x$. Thus for $r<r_0^N$, the marginal price schedule crosses the willingness to pay schedule from below at the quantity demanded by a consumer at distance r from the mill,

(20)

$$x^N(r)=(1/\beta)(\alpha-k-t-((b+1)/b)cr),$$

see Figure 1.

Given the optimal nonlinear price schedule obtained above, we may calculate profit π^N, total output X^N, and aggregate net welfare W^N. Profit is given by

(21)

$$\pi^N=\int_0^{r_0^N}\left[\int_0^{x^N(r)}(p(x)-k)\,dx\right]g(r)\,dr$$

$$=\frac{a}{2\beta(b+1)}\left[(\alpha-k-t)^2(r_0^N)^b-\frac{(b+1)^2c^2}{b(b+2)}(r_0^N)^{b+2}\right]$$

$$=\frac{a}{\beta(b+1)(b+2)}\left(\frac{b}{c(b+1)}\right)^b\times(\alpha-k-t)^{b+2}.$$

Similarly for total output we obtain

(22) $$X^N=\int_0^{r_0^N}x^N(r)g(r)\,dr$$

$$=\frac{a}{\beta}\left[(\alpha-k-t)(r_0^N)^b-c(r_0^N)^{b+1}\right]$$

$$=\frac{a}{\beta(b+1)}\left(\frac{b}{c(b+1)}\right)^b(\alpha-k-t)^{b+1}.$$

Consumer welfare is defined as total utility net of production and transport costs.

(23) $$W^N=\int_0^{r_0^N}\left[u(x^N(r))-c(r,x^N(r))-kx^N(r)\right]g(r)\,dr$$

$$=\frac{a}{2\beta}\left[(\alpha-k-t)^2(r_0^N)^b-2\frac{b}{b+1}\times(\alpha-k-t)c(r_0^N)^{b+1}+\frac{(b^2-1)c^2}{b(b+2)}(r_0^N)^{b+2}\right]$$

$$=\frac{a}{\beta}\frac{2b+1}{(b+1)^2(b+2)}\left(\frac{b}{c(b+1)}\right)^b\times(\alpha-k-t)^{b+2}.$$

III. Comparison with Price Discrimination

Given the assumptions made in the previous section, the firm practicing local price discrimination charges $q(r)$ at distance r,

(24) $$q(r)=(1/2)(\alpha+k)-(1/2)(t+cr).$$

As is well known, the optimal spatial price involves absorbing half of the per unit transport costs at each location. Solving for the demand of a consumer at distance r yields

$$(25)\quad x^D(r)=(1/2\beta)(\alpha-k-t-cr)$$

so that the marginal consumer is located at the critical distance r_0^D, where

$$(26)\qquad r_0^D=(1/c)(\alpha-k-t).$$

As before we may calculate profit π^D, total output X^D and aggregate net welfare W^D.

$$(27)\quad \pi^D=\int_0^{r_0^D}(q(r)-k)x^D(r)g(r)\,dr$$

$$=\frac{a}{2\beta(b+1)(b+2)c^b}(\alpha-k-t)^{b+2}$$

$$(28)\quad X^D=\int_0^{r_0^D}x^D(r)g(r)\,dr$$

$$=\frac{a}{2\beta(b+1)c^b}(\alpha-k-t)^{b+1}$$

$$(29)\quad W^D=\int_0^{r_0^D}\left[u\left(x^D(r)\right)-c\left(r,x^D(r)\right)\right.$$

$$\left.-kx^N(r)\right]g(r)\,dr$$

$$=\frac{3a}{4\beta(b+1)(b+2)c^b}(\alpha-k-t)^{b+2}.$$

A comparison of the critical distance under nonlinear pricing r_0^N (equation (19)) with the critical distance under local price discrimination r_0^D (equation (26)) implies the following result.

PROPOSITION 1: *The market area under nonlinear pricing is smaller than the market area under discriminatory local pricing, that is,* $r_0^N<r_0^D$.

Comparison of mill profits and output and consumer welfare under the two pricing policies shows that their relative values depend entirely upon the spatial distribution of consumers.

PROPOSITION 2: *If consumer density de creases, remains constant or increases wit increasing distance from the mill,* $b\lesseqgtr 1$, *the the mill's profits and output and consume welfare under nonlinear pricing are greate than, equal to or less than profits, output, an welfare under local price discrimination, tha is,* $\pi^N\gtreqless\pi^D$, $X^N\gtreqless X^D$ *and* $W^N\gtreqless W^D$.

Proposition 2 implies that nonlinear pric ing is only preferable to local price dis crimination from either a profit or welfar point of view when consumer densit decreases with distance from the mill. Thi might occur in such markets as densel populated city centers or linear markets wit sparsely populated areas between cities. I markets with an even distribution of popula tion within a circle of the mill, local pric discrimination is preferable. These compari sons depend upon the exogeneity of trans port costs. It is shown in the next sectio that nonlinear pricing is preferable whe transport costs are set endogenously by a railroad even when consumer density in creases with distance from the mill as long a the dispersion parameter is not too large.

To better understand the comparison o profit levels under the two pricing policies calculate the profits from an individual a distance r from the mill:

$$(30)\quad \pi^N(r)=\frac{1}{2\beta(b+1)}\left[(\alpha-k-t)^2\right.$$

$$\left.-(b+1/b)^2c^2r^2\right];$$

$$(31)\quad \pi^D(r)=(1/4\beta)\left[(\alpha-k-t)^2\right.$$

$$\left.-2(\alpha-k-t)cr+c^2r^2\right].$$

These profit functions are shown in Figure 2. Note first that profits at the mill under nonlinear pricing $\pi^N(0)$ are greater than, equal to or less than profits at the mill under local price discrimination $\pi^N(0)$, depending upon whether $b\lesseqgtr 1$. Secondly, as the dispersion parameter b increases the location of the marginal consumer under nonlinear pricing approaches that of the marginal consumer under discriminatory pricing. Therefore, as b

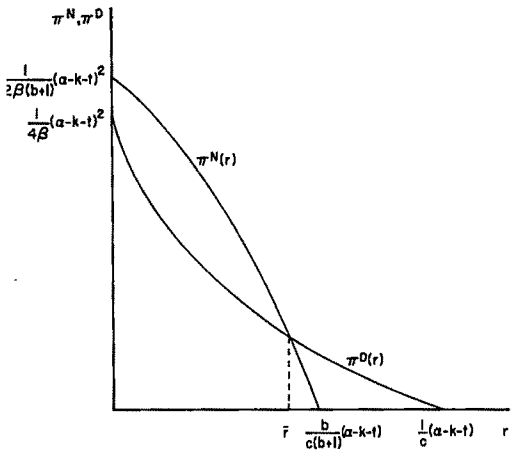

FIGURE 2. PROFIT UNDER NONLINEAR PRICING AT DISTANCE r: $\pi^N(r)$ FOR $b<1$; PROFIT UNDER PRICE DISCRIMINATION AT DISTANCE r: $\pi^D(r)$

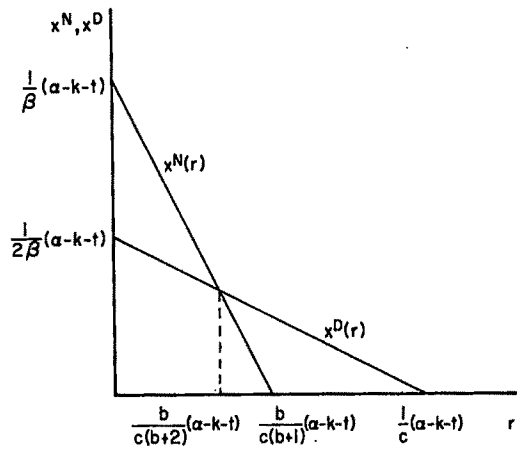

FIGURE 3. DEMAND UNDER NONLINEAR PRICING AT DISTANCE r: $x^N(r)$; DEMAND UNDER PRICE DISCRIMINATION AT DISTANCE r: $x^D(r)$

increases, the slope of $\pi^N(r)$ becomes flatter,

$$(32)\quad \frac{d^2\pi^N(r)}{db\,dr} = -\frac{(b+2)}{\beta b^3}c^2 r < 0.$$

Clearly, by Proposition 2, when consumer density is uniform with regards to distance from the mill, the area under the two curves is equal. Thus while the nonlinear pricing firm serves a smaller market, it extracts greater profits from each of the consumers it serves than does the price discriminating firm. This is because quantity discounts allow the nonlinear pricing firm to capture a greater amount of consumer's surplus from an individual consumer than can be obtained using a linear price. Therefore, when $b<1$, the combined effects of a steeper profit function and a greater density of consumers nearer to the mill imply that profits will be greater under nonlinear pricing. Conversely, when $b>1$, the profit curve is flattened as the firm attempts to increase its profits from more distant consumers. Given a greater density of consumers farther from the mill, particularly those excluded by nonlinear pricing, profits will then be greater under local price discrimination.

In Figure 3 we compare demand at each location under nonlinear and discriminatory pricing, where $x^N(r)$ and $x^D(r)$ are given by equations (20) and (25). The nonlinear pricing firm always sells more to consumers living nearby $(r<b(\alpha-k-t)/c(2+b))$ than does the discriminatory pricing firm due to its use of quantity discounts. As b increases, the nonlinear pricing firm's market area and output per consumer increases. However, if the density of consumers increases with the distance from the mill $b>1$, the higher output sold farther away by the price discriminating firm is sufficient to lead to a higher total output under price discrimination.

Finally, we compare the net welfare levels for each consumer under the two pricing policies:

$$(33)\quad W^N(r) = \frac{1}{2\beta}\left[(\alpha-k-t)^2 - 2(\alpha-k-t)cr + \frac{b^2-1}{b^2}c^2r^2\right];$$

$$(34)\quad W^D(r) = \frac{3}{8\beta}\left[(\alpha-k-t)^2 - 2(\alpha-k-t)cr + c^2r^2\right].$$

See Figure 4. Note that $W^N(r)$ is concave, linear, or convex depending upon whether b

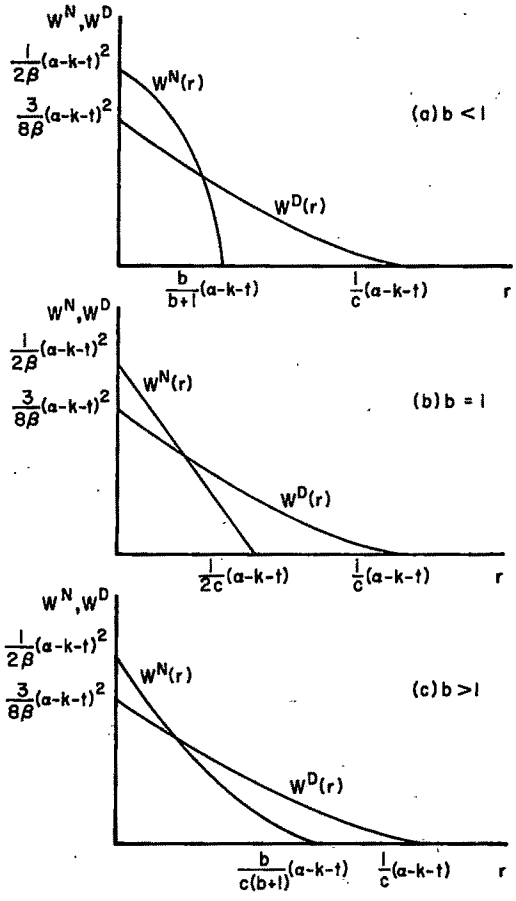

FIGURE 4. WELFARE UNDER NONLINEAR PRICING AT DISTANCE r: $W^N(r)$; WELFARE UNDER PRICE DISCRIMINATION AT DISTANCE r: $W^D(r)$

is less than, equal to or greater than one. This effect reinforces the effect of consumer density on total welfare under nonlinear pricing. The welfare of consumers located near the firm is always greater under nonlinear pricing. When $b<1$, the concavity of the welfare curve and the greater density of consumers near the mill lead to a higher welfare level under nonlinear pricing. When $b=1$, the areas under the welfare curves are equal. Finally, when $b>1$, the convexity of the welfare curve, the lower density of consumers near the mill and the smaller market area lead to a lower welfare level under nonlinear pricing.

IV. The Railroad and the Mill: Noncooperative Equilibrium

Suppose that a railroad firm is the only supplier of transportation available to consumers purchasing the mill's output. By charging consumers a distance tariff based upon the distance from the mill the railroad is able to practice local price discrimination. This section will examine and compare the Nash noncooperative equilibria which result when the mill follows either a nonlinear pricing policy or local price discrimination.

Consider the noncooperative game for the case where the mill follows a nonlinear pricing policy. Both the railroad and the mill make conjectures regarding the form of the other firm's pricing policy. These conjectures are verified at the Nash equilibrium. In particular, the railroad conjectures that the mill's equilibrium marginal price schedule $p(x)$ has the form $p^*(x)=w^*-z^*x$. The mill conjectures that the railroad's equilibrium distance charge $d(r)$ has the form $d^*(r)=t^*+c^*r$. Assume that the railroad has the cost function $c(r,x)=hrx$. The mill's problem was solved in Section II and the optimal price schedule is given by

$$(35)\quad p(x)=(1/(b+1))(bk+\alpha-t^*-\beta x).$$

The railroad maximizes profits given the consumer demand function

$$(36)\quad x(d)=(\alpha-w^*-d)/(\beta-z^*).$$

The railroad's problem is then,[6]

$$(37)\quad \max_d (d-hr)\left(\frac{\alpha-w^*-d}{\beta-z^*}\right)$$

for all r on the unit interval. Therefore,

$$(38)\quad d(r)=(1/2)(\alpha-w^*+hr).$$

Solving (35) and (38) for (w^*, z^*, t^*, c^*), we obtain $w^*=(2bk+\alpha)/(1+2b)$, $z^*=\beta/(1+b)$, $t^*=b(\alpha-k)/(1+2b)$ and $c^*=h/2$.

[6]As noted by Damus, the calculation of profit-maximizing distance tariffs given a linear demand for transport was obtained by Charles Ellet and generalized by Wilhelm Launhardt.

PROPOSITION 3: *Given nonlinear pricing by the mill, there exists a noncooperative equilibrium in price schedules* $(p^*(x), d^*(r))$ *given by*

$$p^*(x)=\frac{2bk+\alpha}{1+2b}-\frac{\beta}{1+b}x; \tag{39}$$

$$d^*(r)=\frac{b(\alpha-k)}{1+2b}+\frac{h}{2}r. \tag{40}$$

At the noncooperative equilibrium the amount purchased by a consumer at distance r from the mill is given by

$$x^N(r)=\frac{1+b}{\beta b}\left[\frac{b}{1+2b}(\alpha-k)-\frac{h}{2}r\right]. \tag{41}$$

Therefore, the critical distance beyond which demand is zero is

$$r_0^N=\frac{2b}{(1+2b)h}(\alpha-k). \tag{42}$$

The mill's profit and output level[7] and consumer welfare at the noncooperative equilibrium may be easily calculated by substituting (t^*, c^*) for (t, c) in equations (21), (22) and (23).

$$\pi^N=\frac{a(b+1)}{\beta(b+2)(2b+1)^2}\times\left(\frac{2b}{h(2b+1)}\right)^b(\alpha-k)^{b+2} \tag{43}$$

$$X^N=\frac{a}{\beta(2b+1)}\times\left(\frac{2b}{h(2b+1)}\right)^b(\alpha-k)^{b+1} \tag{44}$$

$$W^N=\frac{a}{\beta(b+2)(2b+1)}\times\left(\frac{2b}{h(2b+1)}\right)^b(\alpha-k)^{b+2}. \tag{45}$$

[7]It can be shown that there are returns to vertical integration.

Consider now a noncooperative equilibrium in which the mill practices local price discrimination. Proceeding as before, the railroad conjectures that the mill's equilibrium pricing policy has the form $q^*(r)=\gamma^*+\sigma^*r$, and the mill conjectures that the railroad's equilibrium distance charge has the form $d^*(r)=t^*+c^*r$. The mill's problem was solved in Section 3 and the optimal price at location r is given by

$$q(r)=(1/2)(\alpha+k)-(1/2)(t^*+c^*r). \tag{46}$$

Given the demand function at r,

$$x(d,r)=(1/\beta)(\alpha-\gamma^*-\sigma^*r-d) \tag{47}$$

the railroad's profit-maximizing transport charge is

$$d(r)=(1/2)(\alpha-\gamma^*+(h-\sigma^*)r). \tag{48}$$

Solving (46) and (48) for $(\gamma^*, \sigma^*, t^*, c^*)$ we obtain $\gamma^*=(\alpha+2k)/3$, $\sigma^*=-h/3$, $t^*=(\alpha-k)/3$ and $c^*=2h/3$.

PROPOSITION 4: *Given that local price discrimination is practiced by the mill, there exists a noncooperative equilibrium in price schedules* $(q^*(r), d^*(r))$ *given by*

$$q^*(r)=(\alpha+2k)/3-(h/3)r; \tag{49}$$

$$d^*(r)=(\alpha-k)/3+(2h/3)r. \tag{50}$$

The equilibrium demand at distance r from the mill is given by

$$x^D(r)=(1/3\beta)(\alpha-k-hr). \tag{51}$$

Therefore, the critical distance beyond which demand is zero is

$$r_0^D=(\alpha-k)/h. \tag{52}$$

A comparison of the critical distance at the equilibrium with nonlinear mill pricing r_0^N (equation (42)) with the critical distance at the equilibrium with local price discrimination r_0^D (equation (52)) implies:

PROPOSITION 5: *The market area is smaller at the noncooperative equilibrium with nonlinear pricing than at the noncooperative equilibrium with discriminatory local pricing, that is,* $r_0^N < r_0^D$.

Substituting for (t^*, c^*) in (27)–(29), we obtain the mill's profit[8] and output and net consumer welfare at the noncooperative equilibrium with discriminatory mill pricing:

$$\pi^D = \frac{2a}{9\beta(b+1)(b+2)h^b}(\alpha-k)^{b+2}; \tag{53}$$

$$X^D = \frac{a}{3\beta(b+1)h^b}(\alpha-k)^{b+1}; \tag{54}$$

$$W^D = \frac{a}{3\beta(b+1)(b+2)h^b}(\alpha-k)^{b+2}. \tag{55}$$

Comparison of mill profits and output and consumer welfare under the two pricing policies yields the following result:

PROPOSITION 6: *If consumer density does not increase too rapidly with increasing distance from the mill* $0<b\leqslant 2$, *then the mill's profits, output and consumer welfare are greater at the noncooperative equilibrium with nonlinear pricing than at the noncooperative equilibrium with discriminatory local pricing, that is,* $\pi^N > \pi^D$, $X^N > X^D$, *and* $W^N > W^D$.

The higher profits, output and welfare with nonlinear mill pricing hold for uniform distribution of consumers along a line ($b=1$) as well as for uniform distribution of consumers in the plane ($b=2$).[9] The results differ from *Proposition* 2 in that profits, output and welfare may be greater even with increasing density as one moves away from the mill. An important reason for this difference is that at the noncooperative equilibrium, the conveyance rate is equal to $h/2$ when the mill offers a nonlinear price schedule and is equal to $2h/3$ when the mill practices local price discrimination. The terminal charge when the mill offers a nonlinear price schedule is greater than, equal to, or less than the terminal charge when the mill practices local price discrimination as b is greater than, equal to or less than one. Thus the mill is better able to compete against the railroad by employing nonlinear pricing if consumers are not overly dispersed. The lower transport charges also lead to higher output and consumer welfare levels. A comparison of output, profits and welfare levels for each consumer at a given distance from the mill is similar to the discussion at the end of Section III. Graphs similar to Figures 2, 3, and 4 are obtained.

V. Conclusion

The results in this paper suggest that a firm with information about the spatial distribution of its customers which cannot practice local price discrimination, will take advantage of varying consumer marginal willingness to pay due to transport costs by offering a nonlinear price schedule at the mill. Given exogenous transport costs, nonlinear mill pricing is shown to maximize profits and to result in higher output and greater consumer welfare as compared to local price discrimination if and only if consumer density does not increase with increasing distance from the mill. At a noncooperative equilibrium with freight rates set by a transport firm the conveyance rate is shown to be lower when the mill offers a nonlinear price schedule. This results in greater profits,

[8]As may be expected, there are returns to vertical integration. The delivered price at the noncooperative equilibrium is $q^*(r)+d^*(r)=(2\alpha+k+hr)/3$. The optimal delivered price when the mill and the railroad are controlled by a single firm is the well-known expression $(\alpha+k+hr)/2$ which involves absorption of half of the freight by the firm.

[9]The condition on the dispersion parameter b given in Proposition 5 is not a necessary condition. The output and welfare comparisons hold for higher values of b but not for b sufficiently large. Note that

$$\frac{X^N}{X^D} = \frac{W^N}{W^D} = \frac{3(b+1)}{2b+1}\left(\frac{2b}{2b+1}\right)^b$$

So,

$$\lim_{b\to\infty}\frac{X^N}{X^D} = \lim_{b\to\infty}\frac{W^N}{W^D} = \frac{3}{2}\cdot e^{-1/2}$$

$$\approx .9098 < 1.$$

Note also that for $b=3$, $W^N < W^D$.

output, and consumer welfare under nonlinear pricing even when consumer density increases with increasing distance from the mill.

The mill's choice of a pricing policy is constrained by legal and informational considerations. The analysis in this paper implies that the mill's pricing policy also depends in a significant way upon the spatial distribution of its potential customers and the degree of competition in the transportation market.

A problem for future research is the effect of competition and free entry of other producers on the equilibrium mill price schedule. My earlier paper examined nonlinear price competition in a differentiated industry. This analysis might be extended to a framework where goods are spatially differentiated. The firms could compete by varying their location as well as the shape of their nonlinear price schedules. The introduction of competition with nonlinear pricing to a spatial setting may yield interesting results regarding the equilibrium number and size of firms.

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Duopoly Models with Consistent Conjectures

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The theory of oligopoly price is very sensitive to behavioral assumptions. Even given identical assumptions about costs and demand, different models can predict every price between marginal cost and monopoly. This paper selects a single oligopoly model, and thus predicts a single oligopoly price. The selection criterion is consistency of conjectures; each firm's conjectures about the way other firms react to it will be correct.

The two classical oligopoly theories, Bertrand and Cournot, make identical assumptions about costs and demand, but different assumptions about firm behavior. In Cournot equilibrium, each firm maximizes profit given the *quantity* of output other firms produce. In Bertrand equilibrium, each firm maximizes given the *prices* other firms charge. This difference in behavioral assumptions leads to a large divergence in predicted prices. Cournot predicts positive markups that decline as the number of firms increases, while Bertrand predicts marginal cost pricing even in duopoly. Clearly both models cannot be correct. Is their truth an empirical question, as recent work suggests?[1] This paper attempts to decide on theoretical grounds.

No attempt to decide among Bertrand, Cournot, and their more modern competitors can be based on mathematical correctness. Economic criteria must guide the decision. Oligopoly models are examples of what game theorists call Nash equilibrium. In them, every firm maximizes profits given the actions of all other firms. The mathematics does not care whether "actions" are defined to be prices (Bertrand), quantities (Cournot), or any other variables. Yet these distinctions are crucial to the economics of the situation. The notion of Nash equilibrium already entails one economic condition—individual rationality. This paper will determine the correct definition of actions by imposing a further economic condition—consistency of conjectures.[2]

The precise sense in which conjectures are to be consistent is this; the *conjectural variation* and the *reaction function* will be equated. The conjectural variation is the firm's conjecture about other firms' behavior. In Cournot, for example, each firm conjectures that all other firms' quantities are constant. The reaction function is the firm's actual behavior. It is the solution to the profit-maximizing problem, and tells what the firm will do as a function of all other firms' actions. Clearly, what the firm conjectures affects how it reacts. This paper will search for cases where conjectures and reactions are the same—where each firm's conjectures about other firms' reactions are perfectly correct, locally.[3]

Every notion of Nash equilibrium has the feature that, in equilibrium, each firm's beliefs about the *level* of all other firms' actions are confirmed. For example, in Cournot duopoly, each firm's equilibrium quantity is that one which induces the other firm to produce its equilibrium quantity. The firms are right in their beliefs, in Fellner's famous remark, but right for the wrong reason. That is, it is not actually true, as conjectured by the firm, that the other firm's quantity is a constant. The other firm's quantity depends nontrivially on ours—the reaction function does not have zero slope, although the conjecture does. This paper will find Nash equilibrium notions in which firms are right for

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[1]Two recent papers treating the oligopoly equilibrium notion as an empirical question are Elie Appelbaum and my own.

[2]A review of oligopoly models, of the idea that they can predict any prices, and of the notion of "conjecture" can be found in William Fellner or James Friedman.

[3]Similar notions of consistency have been taken up independently by other researchers. See John Laitner, David Ulph, and Morton Kamien and Nancy Schwartz.

ıe right reason. In equilibrium, they will be orrect not only about the *levels* of one nothers' actions but also about the *functions* ccording to which they are reacting.[4] One ıight view this as a kind of rational expecta- .ons oligopoly theory. Consistency of con- ectures makes the way firms react to one nother endogenous by requiring that it be orrect.

In the next section, a consistent conjec- ıres equilibrium (*CCE*) is defined. A series f examples show what *CCE* price is under ifferent assumptions about cost and de- ıand. For example, with constant marginal osts the Bertrand conjectures (which imply ıarginal cost pricing) are consistent. A sec- ınd section gives the central theorem of the ›aper: Under certain assumptions about cost ınd demand, the *CCE* exists and is unique. Jniqueness is a very important property— vhen the *CCE* is unique, consistency of con- ectures solves the problem of too many ›ligopoly solution concepts by determining a ingle equilibrium price and quantity. Sec- ion III points out two ways in which in- reasing returns to scale could cause nonex- stence of the *CCE*. Section IV investigates he role of the *CCE* when the conditions of he duopoly are set by firm's investments in apacity. It concludes that, with constant eturns, capacity cannot serve as a barrier to ntry. Defense of the *CCE* as a sensible way o solve the oligopoly problem is postponed ıntil Section V.

I

This section establishes notation and de- ines a consistent conjectures equilibrium. In he classical case studied by Bertrand and Cournot (constant marginal cost) it is shown hat the Cournot equilibrium is not a *CCE*. t is further shown that the Bertrand equi- ibrium is a *CCE* in this case. The section concludes by examining two examples in vhich the *CCE* lies between Bertrand and Cournot, depending on the cost and demand functions.

The quantity produced by firm i ($i=1,2$) is labelled q_i. The vector of both firms' outputs is called q:

$$q \equiv (q_1, q_2). \tag{1}$$

If the products are perfect substitutes, it will be convenient to define the industry quantity, Q:

$$Q \equiv q_1 + q_2. \tag{2}$$

Let us assume that the inverse demand functions are all defined. The notation for demand is

$$P_i = P_i(q_1, q_2). \tag{3}$$

When the products are perfect substitutes, (3) takes the form

$$P_i = P = P(Q). \tag{4}$$

The costs to firm i are given by the cost function $c_i(q_i)$.

Let us use the notational convention of Lester Telser and write all oligopoly solution concepts as if they had quantities as strategic variables. To do this, we adopt the idea of conjectural variation, r. Firm i acts as if it believes

$$\partial q_j / \partial q_i = r_{ij}(q_i) \text{ for } j=1,2; j \neq i. \tag{5}$$

Throughout, it shall be maintained the convention that firm j is the other firm when speaking about firm i. The observable implication of (5) is that firm i acts as if it believes that it faces a demand curve with slope

$$\frac{dP_i}{dq_i} = \frac{\partial P_i}{\partial q_i} + \frac{\partial P_i}{\partial q_j} r_{ij}(q_i). \tag{6}$$

Some examples may clear up the notion of conjectural variation. Let the two products be perfect substitutes. Then firm 1 acts as if it faces a demand curve with slope

$$dP/dq_1 = P'(Q)(1 + r_{12}(q_1)). \tag{7}$$

[4]The phrase "consistency of conjectures" or similar ones have sometimes been used to indicate correctness about the levels of strategic variables. This paper adapts the more common usage and calls correctness about levels "being in equilibrium."

Thus, if $r_{12}=0$, firm 1 is a Cournot player. If $r_{12}=-1$, firm 1 is a Bertrand player, since in this case total quantity, and therefore price, is conjectured to be a constant. If $r_{12}=1$, firm 1 acts like a colluder. In this case, the firm acts as if it can affect total output, but not its own market share. If $r_{21}=r_{12}$ in any of the above cases, then the reaction functions yield the named equilibrium concepts—Cournot, Bertrand, or Collusion. Of course, $r_{ij}(q_i)$ could be a more complicated function, and r_{12} need not equal r_{21}. What is important here is that assumptions about r are assumptions about the equilibrium concept.

We now examine the impact of the solution concept, that is, the r, on firm behavior. The profit function for firm i is

$$\Pi_i=P_i(q)q_i-c_i(q_i). \tag{8}$$

The corresponding first-order condition for a profit maximum is

$$0=q_i\left(\frac{\partial P_i(q_1,q_2)}{\partial q_i}+\frac{\partial P_i(q_1,q_2)}{\partial q_j}r_{ij}(q_i)\right)+P_i(q_1,q_2)-\frac{\partial c_i(q_i)}{\partial q_i}, \tag{9}$$

which implicitly defines q_i in terms of the quantity produced by the other firm, q_j. The reaction function ρ is defined by

$$q_i=\rho_i(q_j) \text{ solves (9).} \tag{10}$$

What function ρ is depends on r_{ij} as well as on the cost and demand functions. Note that in (9), the actual q_j enters even though firm i supposedly has conjectures about what q_j will be. These conjectures, therefore, are unlike those of a Stackelberg leader. In the present model, each firm does in fact react to the other, in a way that depends on conjectures. For any given conjectures, we could define an oligopoly equilibrium point, q^*, in the usual way:

$$\text{if } q_1^*=\rho_1(q_2^*) \text{ and } q_2^*=\rho_2(q_1^*), \tag{11}$$

then q^* is an equilibrium. I now extend this definition so that the conjectures are corre as well.

Definition: A consistent conjectures equ librium is a pair of quantities q^*, and conjectures $(r_{12}(q_1), r_{21}(q_2))$, such that

$$q_1^*=\rho_1(q_2^*),\ q_2^*=\rho_2(q_1^*), \tag{12}$$

and there is some $\varepsilon>0$, such that

$$r_{12}(q_1)=\frac{\partial\rho_2(q_1)}{\partial q_1} \tag{13}$$

for all $q_1^*-\varepsilon<q_1<q_1^*+$

$$r_{21}(q_2)=\frac{\partial\rho_1(q_2)}{\partial q_2} \tag{14}$$

for all $q_2^*-\varepsilon<q_2<q_2^*+$

The way to read (13) is: r_{12} is one's conje ture about two, ρ_2 two's actual behavior. I this definition (12) assures that both firm are correct about the *level* of one another' reaction functions. This is merely the usu Nash equilibrium condition. What (13) an (14) assure is that the firms are correct abou the higher order derivatives as well. Perhap the definition can be clarified by the familia observation that the Cournot conjectures an reaction functions are not the same.

Example 1: Cournot equilibrium is not *CCE* when marginal costs are constant, de mand is linear, and products are perfect sub stitutes. Recall that the Cournot solutio concept is defined by $r_{12}=r_{21}=0$. With con stant marginal cost $\partial c/\partial q_i$, firm 1's profit i given by

$$\Pi_1=[P(Q)-\partial c/\partial q_i]q_1, \tag{15}$$

and the analog of (9) is

$$q_1P'(Q)+p(Q)-\partial c/\partial q_i=0. \tag{16}$$

An implicit differentiation gives the slope o 1's reaction function:

$$\partial\rho_1/\partial q_2=-P'(Q)/2P'(Q)=-1/2 \tag{17}$$

Exactly the same analysis could be carried out for firm 2, yielding

$$(18)\quad \partial\rho_2/\partial q_1 = -P'(Q)/2P'(Q) = -1/2$$

If the Cournot conjectures are to be consistent, (17) and (18) must be zero. Since they are equal to $-1/2$ everywhere, the Cournot conjectures are inconsistent, as is well known. Each firm assumes that the other firm's quantity is constant. Yet each firm, because of that assumption, has a reaction function which is not a constant. The firms optimal behavior differs from their assumption about one another's behavior.

The Cournot example makes clear that Cournot firms are not very sophisticated. I will not proceed by giving firms more sophisticated behavior: quite the reverse. We will look for those conjectures which are held by the firm to be certainly true, and which just happen to turn out to be correct. The spirit of this enterprise is therefore not one of giving firms discretion, but of removing their discretion by imposing correctness. Let us now search for the *CCE* under the same constant marginal cost assumption.

Example 2: Under the constant *mc* assumption, the Bertrand equilibrium is a *CCE* for any demand function $P(Q)$. Let the firms have identical linear conjectures with slope r. That is, $r_{12}=r_{21}=r$. Then the first-order condition for firm 1 is

$$(19)\quad (1+r)q_1P'(Q)+P(Q)-\partial c/\partial q_i=0.$$

and the slope of the reaction function is

$$(20)\quad \frac{\partial\rho_1}{\partial q_2} = -\frac{P'(Q)+(1+r)q_1P''(Q)}{(2+r)P'(Q)+(1+r)q_1P''(Q)}.$$

Note that if $r=-1$(Bertrand), then the reaction function has slope -1 as well. Since the situation is symmetric, firm 2's reaction function has the same slope. Therefore the Bertrand equilibrium is a *CCE* for this case.

The economic intuition of this example is straightforward. Recall that the Bertrand equilibrium has price equal to marginal cost. Suppose that one duopolist's behavior is: charge marginal cost and meet all demand. The only possible action for the other firm is marginal cost pricing. No action that attempts to reduce industry quantity can work, since the first firm will meet demand at marginal cost.

The conclusion that the Bertrand equilibrium is the *CCE* depends in a critical way on the cost and demand assumptions of the classical models. Let us now consider two examples in which those assumptions are relaxed. In the first of these, the constant marginal cost assumption is relaxed, and the marginal cost function is allowed to slope up. As the slope moves from horizontal to vertical, the *CCE* moves from Bertrand to Cournot.

Example 3: Let the total cost function be quadratic:

$$(21)\quad c(q_i)=c_0+c_1q_i+c_2(q_i)^2/2,$$

with c_0, c_1, c_2 all nonnegative. Further, let $P(Q)$ be linear with slope d. With a linear conjecture with slope r_{12}, firm 1's first-order condition is

$$(22)\quad P(Q)+d(1+r_{12})q_1 - (\partial c(q_1)/\partial q_1)=0.$$

The derivative of 1's reaction function is then

$$(23)\quad \partial\rho_1/\partial q_2 = -d/[(2+r_{12})d-c_2].$$

A straightforward calculation (shown in the Appendix) yields the slopes at the *CCE*. These equate the rs to the ρs.

$$(24)\quad r_{12}=r_{21} = -1+c_2[1-(1-4d/c_2)^{1/2}]/2d$$

As can be seen by inspection, the slopes of the consistent conjectures in this case lie between 0 (Cournot) and -1 (Bertrand). The *CCE* is determined by the ratio of the slopes of the marginal cost and demand functions. When that ratio is zero (constant marginal cost) the *CCE* is Bertrand equilibrium. As the ratio approaches infinity

(vertical *mc*) the *CCE* approaches Cournot equilibrium. The latter polar case clarifies the intuition; if marginal cost curves are vertical, there are no sensible strategic variables except quantities.

In the next example, the *CCE* departs from Bertrand because the duopolists' products are not perfect substitutes. Again the intuition is clear. One would expect that the closer substitutes products are, the more competitive firm interactions are.

Example 4: Let the inverse demand function be linear and exhibit some product differentiation.

$$(25) \qquad \partial P_i/\partial q_k = d_{ik}; \quad i,k=1,2.$$

Marginal costs are constant at $\partial c/\partial q_i$. In this context, the Cournot conjectures continue to have slope zero. But the slope of the Bertrand conjectures is

$$(26) \qquad r_{ij} = -d_{jj}/d_{ji},$$

which is -1 only if the products are perfect substitutes. In the case of imperfect substitutes, therefore, the Bertrand equilibrium prices are above marginal cost. The *CCE* prices are yet higher. To see this, first calculate the first-order maximum condition for firm i:

$$(27) \quad 0 = P_i(q) - \partial c/\partial q_i + q_i(d_{ii} + d_{ij} r_{ij}).$$

The reaction function has slope:

$$(28) \quad \partial \rho_i/\partial q_j = -d_{ij}/(2d_{ii} + d_{ij} r_{ij}).$$

An easy calculation (see the Appendix) gives the *CCE* conjectures' slopes:

$$(29) \quad r_{ij} = \Big[-d_{ii}d_{jj} + \big[(d_{ii}d_{ij})(d_{ii}d_{jj} - d_{ij}d_{ji})\big]^{1/2}/d_{ij}d_{jj}\Big].$$

Note that the *CCE* conjectures do not involve square roots of negative numbers as long as both demand functions slope down in own price and the products are no more than perfect substitutes. Equation (29) has two interesting polar cases. First, if either d_{1} or d_{21} is zero, the consistent conjectures ar those of Cournot. (And of Bertrand—withou demand-side interaction, all oligopoly solu tion concepts are identical.) Second, if th determinant under the second radical is zero that is, if the products are perfect substitutes the *CCE* is Bertrand. In general, the *CCE* lies between Bertrand and Cournot, with the Jacobian determinant of the demand func tion determining exactly where.

II

This section investigates the (local) sense in which a general linear duopoly has a unique *CCE*. Uniqueness is important, because it shows that the *CCE* does determine a single duopoly equilibrium. Before stating the uniqueness theorem, let us look at one more example, which shows that the conjectures must be completely correct for the *CCE* to be unique.

Example 5: Suppose that firms have nonlinear conjectures ($r_{ij}(q_i)$ not a constant) but that we only require that their conjectures be linearly correct. This partial consistency imposes no restriction on the equilibrium prices and quantities. The example again uses the constant marginal cost case with perfect substitutes. Demand has slope d and cost c'. But now the conjectural variations are quadratic, with slopes:

$$(30) \qquad r_{ij}(q_i) = r_1 + r_2 \cdot (q_i - \theta),$$

where r_1, r_2, and θ are parameters. Then the slope of firm i's reaction function is

$$(31) \quad \partial \rho_i(q_j)/\partial q_j = -1/(2 + r_{ij}(q_i) + r_2 q_i).$$

The limited notion of consistency is this: at the equilibrium quantities, the slopes of the actual reaction functions are equal to the conjectured slopes. The second derivatives are left arbitrary.

With that notion, we can get limited consistency of any reaction slope between 0 and -1. First, set r_1 equal to the desired reaction slope. Set θ equal to the equilibrium quantity at that slope. That leaves this equation for

the reaction slopes at those equilibrium quantities:

$$(32)\quad \partial\rho_i(\theta)/\partial q_j = -1/(2+r_1+r_2\theta)$$

and then r_2 can be picked at will to make the reaction function have slope r_1.

The example clearly generalizes as far as desired. The firms could be incorrect about the forty-second derivative of the reaction function, rather than the second. Prices would still be arbitrary. The sense in which consistent conjectures are correct is therefore quite strong. The reaction functions are exactly the same functions as the conjectures, at least at the equilibrium point.

The assumptions needed for the uniqueness theorem should be familiar from remarks surrounding the examples:

ASSUMPTION 1: *The inverse demand functions are linear in the positive orthant and are truncated at the axes. In the interior of the positive orthant, the Jacobian of the demand system is negative semidefinite. It is negative definite unless the products are perfect substitutes.*

ASSUMPTION 2: *The total cost function is quadratic, positive-valued, increasing, and convex over positive quantities. That is, both total and marginal cost functions slope up.*

These assumptions combine the elements of departure from the classical case of examples 3 and 4.

ASSUMPTION 3: *Fixed costs are not so large as to swamp variable profits, nor are the firms' cost functions so different that one is dominated out of the market.* (This assumption will be made precise in the course of the proof. Without it, uniqueness would not be called into question, but existence would.)

THEOREM 1: *Under Assumptions* 1–3, *there is a CCE with linear conjectures. The CCE is unique in the class of polynomial conjectures.* (Proof is shown in the Appendix.)

Uniqueness in the class of polynomial conjectures is about as strong a result as can be gotten here. The reason for this is that conjectures about behavior far from the equilibrium point are irrelevant. If, say, doubling output were conjectured to cut profit by one-third instead of one-half, there would be no effect on behavior. Precisely the sense in which the *CCE* can be unique is local. The conjectures and the reaction function have the same Taylor series at the equilibrium point. Since the polynomials in the theorem are of arbitrarily large degree, this is what has been proven. For example, it has been shown that the equilibrium notion of Bertrand is the uniquely correct one in the classical case of constant marginal cost.

III

This section presents two examples of nonexistence of the *CCE* under increasing returns to scale. The first of these posits perfect substitutes, constant marginal costs, and nonzero fixed costs. The second example is constructed with a linear, downward-sloping marginal cost function.

When *mc* is constant and products are perfect substitutes, the *CCE* equilibrium concept will be Bertrand. Then equilibrium prices will be equal to *mc*—an unfortunate outcome for firms with fixed costs. Since revenue just covers variable cost, profits will be negative. Exit should follow. This *CCE*, which was an equilibrium given only local information, is not an equilibrium when the total conditions are taken into account. Thus, in this case, there will be no *CCE*.

Example 6: The cost function is the quadratic one of example 3, above. But here $c_0=0$, $c_1>0$, $c_2<0$, so that *mc* slopes down. $P(Q)$ is linear with slope d. The inverse demand function cuts the *mc* curve from above in the positive orthant. I begin by looking for a *CCE* with linear conjectures. The derivatives of the reaction functions are exactly as in example 3, above:

$$(33)\qquad \partial\rho_1/\partial q_2 = -d/(d(2+r_{12})-c_2);$$

$$(34)\qquad \partial\rho_2/\partial q_1 = -d/(d(2+r_{21})-c_2).$$

Imposing the conditions of the *CCE* and

substituting (33) into (34) yields

$$(35)\quad r_{12}\left[2-\frac{1}{2+r_{12}-c_2/d}-\frac{c_2}{d}\right]=-1.$$

The quadratic equation implied has determinant

$$(36)\quad (2-c_2/d)^2-4<0,\ \text{if}\ c_2<0.$$

Thus no linear *CCE* exists for $c_2<0$.[5] Since Lemma 2 (see the Appendix) shows that linear duopolies like this one have linear *CCE*'s if they have any polynomial ones, no polynomial *CCE* exists for this technology.

It is easy to understand the nature of this nonexistence proof, and of the comparable result when the technology has fixed costs and constant marginal costs. In these instances, global increasing returns reign. Any duopoly equilibrium is dominated in cost terms by some single firm outcome. Hence it is the theory of entry, not of duopoly, which determines price. Monopoly equilibria do exist. Thus only equilibria with the cost minimizing number of firms in operation exist.

IV

This section presents an example of capacity investment oligopoly. In it, firms invest in fixed capital in advance of the market period. Then it is the *SR* cost function which is relevant to the market equilibrium. Since the market equilibrium is a *CCE*, there is no intertemporal inconsistency in firms' beliefs about one anothers' behavior. The example explores the nature of capacity as a barrier to entry (see Michael Spence) under the assumption that the post-entry duopoly solution concept is a *CCE*. It clearly shows that capacity alone is not a sufficient barrier with a constant returns Leontief technology.

Example 7: Producers must invest in fixed capital in advance of the market period, and cannot alter their capacity during the market period. The overall production technology is Leontief:

$$(37)\quad q_i=min[L_i/\lambda, K_i/\kappa],$$

where L_i is labor, K_i capital in place, and λ and κ are constants. Label firm i's capacity by $k_i=K_i/\kappa$ Then the short-run (fixed K_i) marginal cost is

$$(38)\quad srmc_i=\begin{cases} c & 0\leqslant q_i<k_i \\ \infty & q_i\geqslant k_i \end{cases}$$

where c is λ times the wage rate. Long-run total costs include a charge for capital, of course. Let f be κ times the interest rate. Then,

$$(39)\quad lrmc_i=c+f.$$

As before, demand is linear: $P=A+d(q_1+q_2)$.

The equilibrium concept has two stages, capacity and market. By imposing *CCE* on the market equilibrium, we insure that perfect foresight at the capacity investment stage involves no inconsistency. As a first step, let us calculate the market *CCE* as a function of capacities. The capacity constraint changes the firms' maximization problems, since profit maxima can come either at an interior solution or at the capacity constraint. The Kuhn-Tucker conditions for a profit maximum are

$$(40)\quad q_i d(1+r_{ij})+P(Q)-c\geqslant 0,$$

$$[q_i d(1+r_{ij})+P(Q)-c][k_i-q_i]=0.$$

In working toward calculation of the *CCE*, it will be useful to have a few points on the mapping from conjectures to reaction slopes on hand, as in Table 1. The table shows what kind of *CCE*s are possible. Both firms could be unconstrained; in this case they will be Bertrand players, as example (2) showed. This occurs only if industry capacity is sufficient to set demand price to c. Alternatively, both firms could be constrained; this occurs when their capacities are both so small that the constraint binds with the (correct) con-

[5]Note that the determinant is positive if $2d<c_2<0$. But then the inverse demand function cuts *mc* from below and the second-order conditions cannot hold.

TABLE 1

Constrained?	Conjecture	Reaction
yes	any	0
no	0	$-\frac{1}{2}$
no	-1	-1

jecture of zero. Lastly, one firm could be constrained (with conjecture $-1/2$) and the other unconstrained (with conjecture 0).

Manipulation of the first-order conditions reveals the regions in capacity space in which each of these equilibria can obtain. In Figure 1, region I has both firms constrained, region II, neither, while in regions III and IV firms one and two only are constrained, respectively. In region V there are two equilibria. Either firm 1 or firm 2 can be constrained but not both.

The nonuniqueness of equilibrium in region V is not disturbing in the context of the two-stage game. Any notion of individual rationality suggests that no firm will invest in capacity and then become unconstrained. Therefore the interior of regions III, IV, and V can be ruled out. On the border, of course, the profits are the same whether the firm is viewed as just constrained or just not. A problem might arise if each firm took the (optimistic) view that it was going to be the constrained firm, even if it had the larger capacity. These mutually inconsistent expectations could lead to inconsistent two-stage equilibria.

More interesting is the light in which this example places the use of capacity as a barrier to entry. How does an incumbent firm's excess capacity serve as a signal of willingness to compete *ex post* entry? If the post-entry solution concept is the *CCE*, capacity does not have the desired effect. With constant returns to scale, the incumbent cannot find a capacity which induces the potential entrant to stay out. This is true even if we assume that the incumbent is a Stackelberg leader in the capacity game. The key to the proof is the nature of the *CCE* when either firm's capacity is small.

To see that capacity cannot be a barrier, assume that firm 1 is the incumbent. Divide

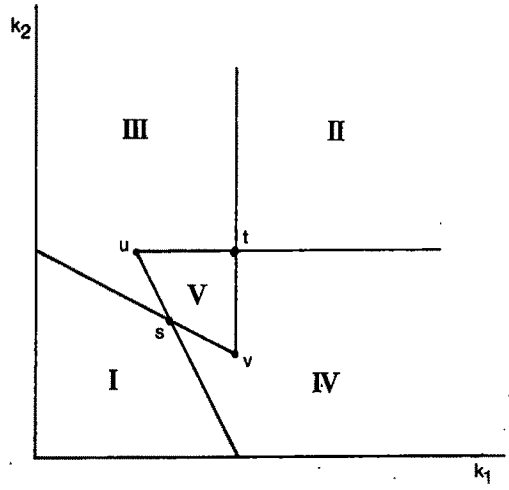

FIGURE 1. $s=\left[\frac{A-c}{-3d},\frac{A-c}{-3d}\right]$; $t=\left[\frac{A-c}{-2d},\frac{A-c}{-2d}\right]$; $u=\left[\frac{A-c}{-4d},\frac{A-c}{-2d}\right]$; $v=\left[\frac{A-c}{-2d},\frac{A-c}{-4d}\right]$.

the problem of the entrant, firm 2, into two cases depending on firm 1's capacity.

Case I: $k_1<-(A-c)/2d$. In this case, if firm 2 enters at small enough capacity, the *CCE* will be in region I, both firms constrained. Therefore, if firm 1 was making positive profits, firm 2 can find a small enough capacity to make positive profits as well.

Case II: $k_1\geqslant-(A-c)/2d$. In this case, firm 1 will have excess capacity even after entry at small k_2. In region IV, where firm 2 is capacity constrained, firm 1 is not. In that region, firm 1 (correctly) conjectures that firm 2's output is constant, while firm 2 knows r_{21} to be $-1/2$. Then the equilibrium market values will be

$$(41)\quad q_2=k_2, q_1=-(A-c)/2d-k_2/2;$$

$$(42)\quad P=A-(A-c)/2+dk_2/2;$$

$$(43)\quad \Pi_2=[(A-c)/2+dk_2/2-f]k_2.$$

Equation (43) says that the condition for firm 2 to be unable to find a capacity invest-

ment which yields positive profit is

$$f > (A-c)/2. \tag{44}$$

But this is exactly the condition that firm 1's monopoly price not cover capital charges should entry be deterred. Thus deterring entry cannot be profitable.

This example shows that excess capacity alone is not a barrier to entry when all players correctly anticipate the post entry equilibrium. This is true even though the incumbent firm can alter the "rules of the game" as well as its "initial conditions" in Avinash Dixit's useful distinction. It is clear from the proof that this result leans heavily on the assumption of constant returns down to arbitrarily small scale.

V

This section defends consistency of conjectures as a reasonable restriction on the oligopoly solution concept. The defense, suprisingly enough, has nothing to do with dynamics. Indeed, the problem of constructing an informationally consistent oligopoly is a formidable one, as yet unsolved. The first half of this section treats dynamic arguments; the results are quite negative. The second half treats the comparative statics of equilibrium; they lead naturally to the *CCE*.

One argument against some oligopoly solution concepts is that they have "inconsistent dynamics." Although I will not use the dynamic inconsistency argument, it is instructive to step through it for Cournot equilibrium. Begin with an arbitrary quantity for firm one, say q_1. Let firm two take q_1 as given and move to its profit-maximizing output, $q_2=\rho_2(q_1)$. Now firm one will move to $q_1=\rho_1(q_2)\ldots$. Continue until convergence at the equilibrium quantities. At every step, each firm has maximized profit, taking the quantity of the other firm as given. Yet the other firm's quantity has in fact changed; the firm should notice this and take advantage of the information. A possible argument for the *CCE* arises from this dynamic inconsistency. If firms' conjectures are everywhere correct, they will be confirmed by these dynamics.

The inconsistent dynamics argument is unsatisfactory because it confuses statics and dynamics. Is it an argument against Cournot equilibrium or against the particular dynamic used to reach it? Economists routinely object to similar cobweb dynamics for perfect competition on rational expectations grounds. Perhaps here, as there, the fault could lie in the dynamic rather than in the equilibrium notion. It would be desirable[6] to construct a better argument, a rational expectations oligopoly, in which dynamic considerations affect the static equilibrium concept. But it is not necessary.

Fortunately, it is not necessary to work out the disequilibrium dynamics of oligopoly to defend the *CCE*. The comparative statics of equilibrium give firms enough information to recover one anothers' behavior. Suppose that some variable exogenous to the oligopoly (say, costs, the location of the demand curve) is changed. Equilibrium prices and quantities will change whatever the nature of the equilibrium concept. Suppose that firms learn nothing about one anothers' behavior from the dynamic process by which the new equilibrium is obtained. They can still learn one anothers' reactions from the location of the new equilibrium. A Cournot firm, knowing the costs, the demands, and that it has reaction slope $-1/2$ can easily learn from the movement of market price the one thing it does not know—the slope of the other firm's reaction. The natural experiment, the

[6]It is quite difficult. The discussions of oligopoly by Takashi Negishi and by D. W. Bushaw and Robert W. Clower (ch. 7) as well as the "conjectural equilibria" of Frank Hahn and Jose Trujillo will be useful in attacking the out-of-equilibrium dynamics. The theory will have to treat several thorny issues. One is a kind of higher-order inconsistency. Suppose constant marginal cost duopolists begin with Cournot ($r=0$) conjectures. Each then observes that the other has a reaction with slope $-1/2$, and updates its conjecture to have this slope. This gives them (optimally: see (23), above) reactions with slope $-2/3$. And this process will continue until they converge to the consistent Bertrand conjectures. Note that the same dynamic inconsistency argument raised against Cournot dynamics can be raised here. The firms are acting as if one anothers' *reactions* are fixed. Why do they not notice that they are changing? In light of this line of argument, I am not sanguine about the possibilities of a fully consistent oligopoly dynamic.

movement of exogenous variables, can reveal to firms that their conjectures are inconsistent. This argument does not depend in any critical way on the belief that the equilibrium comparative statics "actually happen." Consider a two-stage oligopoly like the one in the last section. Firms must first pick capacity, and then, with capacity fixed, price or output. At the first stage the only reasonable expectations to give firms are the correct ones. They should be able to calculate their eventual profits as a function of their capacities. Performing that calculation requires knowledge of the second-stage equilibrium concept. Are we to assume, then, that at the second stage they forget their knowledge of one anothers' behavior? There will be no intertemporal inconsistency in their knowledge if the market equilibrium notion is the *CCE*.

The sense of the *CCE* is then this. If firms have inconsistent conjectures and it is possible for them to learn how their industry reacts to exogenous shocks, they will learn that their conjectures are wrong. If they have consistent conjectures, nothing in the comparative statics of equilibrium will reveal those conjectures to be wrong. By what dynamic process the conjectures will come to be consistent is an unsolved problem, as is the possibility of an informationally consistent, stable dynamic for oligopoly prices and quantities.

VI. Conclusion

This paper has solved, in one sense, "the oligopoly problem." The indeterminacy of duopoly price due to a multiplicity of solution concepts has been removed. The cost of a determinate price is the denial of all discretion in firm behavior.[7] Whether this cost is justified depends on the reasonableness of the conditions imposed.

The reasonableness of the *CCE* as such a condition was discussed in the last section. A second defense can be constructed from the solution yielded by the *CCE*. When products are perfect substitutes and marginal costs are constant, pricing will be competitive. When the marginal cost function slopes up or when products are less perfect substitutes, pricing becomes less competitive. This, I think, is a quite intuitive theory of competition. Competition comes about when increases in quantity have no adverse affects on costs and when products are close substitutes.

Related results hint at but do not resolve a connection between increasing returns to scale and entry. First, in two cases of increasing returns, there is no duopoly *CCE*. Second, capacity cannot serve as a barrier to entry when returns are constant down to arbitrarily small scale.[8] These results seem to point at a theory in which entry is determined by cost-minimizing market structure. More work on this appears warranted.

Appendix: Proof of Theorem 1

Theorem 1 can be proved in two lemmas. The first shows that there is exactly one *CCE* under the assumption that conjectures are linear. The second shows that, when the cost and demand systems are linear, any polynomial conjecture must be linear to be correct.

Recall some notation:

(A1) $$d_{ij} \equiv \partial P_i / \partial q_j,$$

$$c_i(q_i) = c_{i0} + c_{i1} q_i + c_{i2}(q_i)^2/2.$$

(A2) $\rho_i(q_j)$ is firm i reacting to j.

(A3) $r_{ij}(q_i)$ is i's conjecture about j.

LEMMA 1: *Under the assumptions of Theorem 1, there is exactly one CCE with linear conjectures.*

[7]A discussion of the role of discretion in the theory of the firm in general and in industrial organization in particular can be found in Donald Hay and Derek Morris.

[8]Some earlier readers of this paper feel that this suggests that the *CCE* is a "perfectness" notion, alluding to the work of Thomas Marschak and R. Selten. I can see no more than analogy in this, although the suggestion is intriguing.

PROOF:

The first-order conditions are

$$\text{(A4)}\quad 0=P_i-\partial c_i(q_i)/\partial q_i+(d_{ii}+d_{ij}r_{ij})q_i;\qquad i=1,2.$$

The slopes of the reaction functions are

$$\text{(A5)}\quad \frac{\partial \rho_i(q_j)}{\partial q_j}=\frac{-d_{ij}}{2d_{ii}-c_{i2}+d_{ij}r_{ij}};\qquad i=1,2\ j\neq i.$$

Note that the linear economic structure implies that the ρ_{ij} are constant if the r_{ji} are. The *CCE* is defined by setting $\rho_{21}=r_{12}$, $\rho_{12}=r_{21}$. This leaves a quadratic equation in r_{12} and r_{21}. The roots are

$$\text{(A6)}\quad r_{ij}=-\alpha\pm\left[(\alpha)(\alpha-4d_{12}d_{21})\right]^{1/2}/\left[2d_{ij}(2d_{jj}-c_{j2})\right];$$

$$\text{(A7)}\quad \text{where } \alpha\equiv(2d_{11}-c_{12})(2d_{22}-c_{22}).$$

The numbers under the radicals are always nonnegative. $\alpha>0$ since $d_{ii}<0$, $c_{i2}\geqslant 0$. $\alpha>4d_{12}d_{21}$ since the products are assumed to be no more than perfect substitutes.

Equation (A6) seems to imply that there are two *CCE*s. (Not four, since taking the positive radical in r_{12} implies taking it in r_{21}, as well.) One of these is economically meaningless, since it occurs at negative quantities. The true *CCE* is found by taking the positive radical. To see this, substitute (A6) back into the first-order condition (A4):

$$\text{(A8)}\quad 0=P_i-\partial c_i(q_i)/\partial q_i+\left[d_{ii}+\left\{-\alpha\pm\left[(\alpha)(\alpha-4d_{12}d_{21})\right]^{1/2}\right\}/\left[2(2d_{jj}-c_{j2})\right]\right]q_i.$$

Since the markup $P_i-\partial c_i(q_i)/\partial q_i$ is always positive, the sign of q_i depends only on the bracketed term. Expanding the bracket yields

$$\text{(A9)}\quad d_{ii}-\frac{2d_{ii}-c_{i2}}{2}\pm\frac{2d_{ii}-c_{i2}}{2}\left(\frac{\alpha-4d_{12}d_{21}}{\alpha}\right)^{1/2}.$$

Since $d_{ii}<0$, $c_{i2}\geqslant 0$, (A6) is negative if and only if the positive radical is taken. Hence $q_i>0$ only if the positive radical is taken.

It should be mentioned at this point that, in the definition of the *CCE*, we have not allowed firms to shut down. Using only local information, we have no way of telling whether price is over average cost. There are two ways for the total condition to fail. One is if the fixed costs are so high that they overwhelm operating profits. This can clearly be dealt with only by calculating operating profits and assuming fixed costs smaller. The other difficulty arises when the firms are close substitutes and one of them has a cost advantage. For example, when *mc* is constant, and the products perfect substitutes, both firms must have the same *mc* or there is no equilibrium. This, too, is dealt with by direct ruling out under Assumption 3.

The exact assumptions on technology and demand made in Assumption 3 can now be spelled out explicitly. First, let the reaction slopes take on their *CCE* values:

$$\text{(A10)}\quad r_{ij}=-\alpha+\left[(\alpha)(\alpha-4d_{12}d_{21})\right]^{1/2}/\left[2d_{ij}(2d_{jj}-c_{j2})\right].$$

Then write out the equations defining the equilibrium quantities:

$$\text{(A11)}\quad \begin{aligned}(2d_{11}+d_{12}r_{12}-c_{12})q_1+d_{12}q_2&=c_{11}-d_{10}\\ d_{21}q_1+(2d_{22}+d_{21}r_{12}-c_{22})q_2&=c_{21}-d_{20};\end{aligned}$$

the condition for q_i to be positive is then

$$\text{(A12)}\quad \left[2d_{jj}+d_{ji}r_{ji}-c_{j2}\right](c_{i1}-d_{i0})-d_{ij}(c_{j1}-d_{j0})<0.$$

This condition will be satisfied whenever i's zero-quantity markup is not too much less than j's, or when i's demand is suitably independent of j's (in the sense that d_{ij} is small). The other half of Assumption 3 is that no shutdown occur. Using (A4), the condition that firm i's price exceed average cost is

$$\text{(A13)} \qquad mc-ac>q_i\left[d_{ii}+d_{ij}r_{ij}\right].$$

Since the bracketed term is negative, the right-hand side is as well. Thus price can fall below average cost only when average cost exceeds marginal in equilibrium. Since average cost is not falling under Assumption 2, this is only the assumption that the fixed costs are not too large.

LEMMA 2: *In the linear situation of theorem 1, any CCE with polynomial conjectures has linear conjectures. This is a straightforward proof by contradiction. Assume that $r_{12}(q_1)$ and $r_{21}(q_2)$ are polynomials of arbitrarily large order, say of order k. I reproduce the first-order condition*:

$$\text{(A14)} \quad 0=P_i-c'_i(q_i)+q_i\left(d_{ii}+d_{ij}r_{ij}(q_i)\right) \qquad i=1,2 \quad j\neq i.$$

The reaction function is defined by solving (A9) for q_i in terms of q_j. The slope of the reaction function is

$$\text{(A15)} \quad \partial\rho_i(q_j)/\partial q_j=-d_{ij}/(2d_{ii}-c_{i2}+d_{ij}r_{ij}(q_i)+d_{ij}q_i\partial r_{ij}(q_i)/\partial q_i).$$

The denominator of the right-hand side (A14) is a kth order polynomial in q_i. Firm i's reaction function has been assumed to be a polynomial in q_j. Therefore the left-hand side of (A14) is a $k-1$th order polynomial in q_j. Clearly there is no ε neighborhood on which these two assumptions are consistent unless $k=0$, the conjectures are linear.

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A Reexamination of Natural Rate Theory

By COSTAS AZARIADIS*

The past fifteen years have witnessed a resurgence of neoclassical macroeconomics. The key development is the emergence of several related propositions which seek to explain stylized facts of cyclical economic behavior in a manner consistent with modern general equilibrium theory, and to offer guidelines for the proper conduct of monetary policy. These propositions will be given the technical label "natural rate theory" (*NRT*);[1] the best known among them are:[2]

PROPOSITION 1: *Anticipated movements in money supply are neutral, that is, exert no influence on the probability distributions of relative prices, employment or real output in stationary equilibrium. Feedback rules for money supply are similarly neutral.*

PROPOSITION 2: *Unanticipated movements in monetary aggregates are neutral on average, affecting actual economic activity but not its central tendency. Consequently, there exists some measure of average activity, the natural rate of unemployment or output, which is uniquely determined by the "real" structure of the economy and is impervious to nominal forces.*

PROPOSITION 3: *Increased uncertainty about monetary aggregates tends to stabilize employment but erodes the allocative power of price signals.*

PROPOSITION 4: *Policies which, at zero resource cost, remove all uncertainty from the process of money creation are not socially inferior to any other policies.*

All of these propositions rely, to some degree, on the deservedly popular hypothesis that expectations are formed rationally; the top three have had some support from existing time-series evidence;[3] and the top two bear a reassuring resemblance to, and indeed appear to be intuitively obvious generalizations in stochastic environments of, well-known results on the "classical dichotomy."[4]

For these reasons, among others, *NRT* has attracted much attention in the profession and roused the interest of policymakers. Yet, an impartial observer who probes the relevant literature will discover quickly that little work has been done on the microeconomic foundations of that theory since the seminal work of Lucas (1972), and may naively wonder whether *NRT* forms a logically coherent whole.

Digging a bit further into the literature, our observer will find that Propositions 1–4 are offered as properties of stochastic stationary equilibria in model economies which share some features of general equilibrium theory (for example, private ownership, competitive markets, flexible prices) but are

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[1]They are thus distinguished from the broader category "macroeconomic implications of rational expectations" which includes work by Stanley Fischer, Edmund Phelps and John Taylor, and others, with sticky prices.

[2]The original work is in Phelps (1968, 1970), Milton Friedman (1968), Robert Lucas (1973), Thomas Sargent and Neil Wallace (1975, 1976), and Robert Barro (1976). See also useful surveys by Barro and Fischer, Lucas (1977), F. Black, Anthony Santomero and John Seater, and Robert Shiller.

[3]See Lucas (1973) and Barro (1977).

[4]See Don Patinkin, especially ch. 8.

›therwise far removed from the paradigm of Kenneth Arrow and Gerard Debreu.[5]

None of these models include markets for ›ontingent claims; most of them are very ›hort on descriptions of preference orderings ınd production sets, beginning instead with ntuitively "appealing" schedules for supply ınd demand. Prominent among such sched- ıles is some variant of the equation

$$(1) \quad \log y_t = \log k_t + b_t(\log p_t - E_{t-1} \log p_t),$$

vhich relates the quantity supplied in period of the composite commodity "all goods and ervices" to some index of its price and to he mathematical expectation of that price ndex conditioned on all prior information. The constant k_t is the "natural rate of out- ›ut" relevant for period t; and b_t is a de- erministic parameter — the elasticity of ıupply with respect to unanticipated changes n the price level—which may depend on the process of money creation.

If equation (1) does indeed represent ag- gregate behavior of suppliers in some ideal- zed economy, then Propositions 1 and 2 ollow without much further ado. Perfectly ınticipated movements in money supply are ıeutral since they fail to influence the accu- acy of price forecasts. Price forecasts are, of course, confounded by unexpected nominal novements which must trigger some re- ›ponse on the part of suppliers. This phe- ıomenon, says equation (1), is strictly transi- ory because rational price forecasts cannot be biased: as long as $\log p_t = E_{t-1} \log p_t$, the ıverage value of $\log y_t$ is $\log k_t$, and equi- ibrium output cannot stray long from its ıatural rate.[6]

To convince our impartial observer that his crucial equation is valid economic theo- izing, we shall have to show him that it is derived from first principles, that is, from the ıctions of profit- or utility-maximizing in- dividuals in some economy. That turns out to be a difficult undertaking, for all we have to go on is a demonstration by Lucas (1972, p. 118) that a reduced form exists which relates equilibrium output to equilibrium price level *and* to the whole probability distribution of the price level.

Equation (1) is then no more than the first two terms from the Taylor-series expansion of the "true" aggregate supply schedule around $E \log p$. We have no assurance that this infinite series converges fast enough to justify dropping terms of higher order, or that equation (1) retains all the qualitative properties of the true supply schedule.[7]

By now we have seriously strained the credulity of our impartial observer. To maintain his interest in natural rate theory, we must discover whether the fundamental propositions of *NRT* spelled out above are "general theorems." Are these the predictions of a reasonably rigorous neoclassical model of equilibrium, constrained only by the usual continuity and convexity requirements, or are they lesser parables with some instructive content?

General equilibrium tools for this endeavor are readily available in the work of Lucas and are used with minor modifications in the sequel. A special case of the basic model of Lucas is restated as simply as possible in Sections I and II, and put to work in Sections III, IV, and V, which examine, respectively, the nature of anticipated movements in money supply, the determinants of the natural rate of employment, and the social desirability of constant growth rules for money supply. Conclusions appear in Section VI.

I. The Model

The economy I shall use as a proving ground for natural rate theory is one in which Samuelsonian overlapping generations inhabit two Phelpsian islands named, for concreteness, Atlantis and Pacifica. At the beginning of each time period a generation of identical individuals is born which lives for two periods. In any period, then, there

[5]The standard treatment is Debreu, ch. 7.

[6]Of course $E \log p = \log p$ for some $p = p_0$ implies $p_0 < Ep$ and, hence, that the expected value of supply exceeds its natural rate k_t by an amount which depends on higher moments of the probability distribution of p. Shiller and Mats Persson explore the role of price variability in the Phillips curve.

[7]First-order series expansions, for instance, do not retain the curvature properties of the approximand.

coexist two generations of equal size (normalized to unity) and identical preferences, indexed by birth date; it is traditional cruelty to denote by the Saxon adjective "old" the maturer generation and by "young" the more vigorous one.

Consumption occurs only in old age, production takes place only in youth. Each member of the generation currently young may use a constant returns to scale technology to transform n hours of his own leisure endowment $\bar{n}$ into an equivalent amount $y=n$ of a homogeneous, perishable good for which he has no immediate use. As interisland travel is prohibitively costly in this economy, producers must exchange locally their temporarily unwanted output for cash balances with which they finance consumption in old age. Money is thus the only store of value in this economy; existing balances are distributed equally over islands and held exclusively by the old.

A simple additive, twice continuously differentiable function

$$u(c', n)=c'-(1/2)n^2 \tag{2}$$

represents the preferences of individuals over consumption-work bundles. The function $u(\cdot)$ is obviously increasing, concave in future consumption c', and current leisure $\bar{n}-n$; note that variables without primes denote "current" values, primed variables denote "future" values.

This economy experiences movements in relative prices because the distribution of the work force fluctuates: a random fraction $\theta/2$ of newborn individuals is assigned for life to Atlantis, with the remaining $1-\theta/2$ going to Pacifica. Absolute prices also vary because of exogenous fluctuations is the nominal amount of money; cash balances are augmented or shrunk each period by a multiplicative factor x. To rule out wealth redistribution,[8] we assume x is common to all old individuals. The independent, nonnegative stationary random variables θ and x are dis tributed in a known manner over the inter vals $[A, B]$ and $[a, b]$, respectively, with $A>0$ $a>0$ and $B\leqslant 2$. We assume also that θ i symmetric and $E\theta=1$.

To endow nominal movements with rea effects, let us adopt the search theoretic con vention which makes current informatio very expensive relative to dated informatio In particular, agents know all past prices a well as the ruling price in their own island but cannot determine at any finite cost th price which prevails in the other island. Sinc the observed price responds to both nomina and real shocks, the "true" state of nature, θ hides in a noisy price message.

The old do not have to decipher this mes sage; they simply give up their cash balance in return for as much consumption as th competitive goods market will allow them The young have the luxury of learning fron the auctioneer the price at which trade wil occur and *then* deciding how much they wis to work. Any interior solution to the prob lem of maximizing expected lifetime utility conditional on current local price, will equat the marginal disutility of current work wit the expected marginal utility of future con sumption, conditioned again on observe price. In other words, if p=current price i Atlantis, p'=future price, x'=future valu of the transfer variable, y=current work (an goods supply), px'/p'=future consumptio per unit current work, then future consump tion is simply

$$c'=y(px'/p'). \tag{3a}$$

Every interior solution to the maximizatio problem of the typical goods supplier i Atlant satisfies, therefore,

$$y=E[(px'/p')|p]. \tag{3b}$$

Island-wide supply of goods equals $(\theta/2)y$ that is, the number of young persons on th island times the supply by each person.

Recalling that each island possesses at al times one-half the aggregate stock of money it is fairly obvious that the demand for goods in Atlantis is the real value of the loca post-transfer cash balances, $(1/2)\,mx$. Hence

[8]From the second fundamental theorem of welfare economics (Arrow; Debreu, ch. 6), we know that redistribution of endowments will generally affect equilibrium allocations. In monetary growth theory (James Tobin), for example, inflation is a tax on money balances which tends to change the composition of asset portfolios and influence the stationary equilibrium value of capital intensity.

equilibrium we shall have $(\theta/2)y=$ $nx/2)/p$, or

$$y=mz/p \tag{c}$$

here we have defined the new random vari- ›le z from

$$z=x/\theta. \tag{d}$$

Equations (3b) and (3c) completely de- ribe stationary rational-expectations equi- ›ria in Atlantis. The "price" which clears ıe market, however, is not a number but a *nction*, that is, a time-invariant rule of the ırm

$$p=J(m,x,\theta) \tag{a}$$

ıat relates the price level to the random isturbances (x,θ) and to pre-transfer oney balances m. The time invariance of ıe price level does not extend outside the ationary state and J is generally a corre- ›ondence.

Returning to stationary states, note that ıe random shocks x and θ affect the econ- ny *only through their ratio z*. On the guess[9] ıat changes in the state variable m will fect equilibrium prices in proportion and ıantities not at all, we rewrite the price ınction in the form

$$J(m,x,\theta)=m\phi(z). \tag{b}$$

ere m is known to everyone and the func- ›n ϕ is a signal which plays the same role in tional expectations models as price varia- es do in ordinary supply-demand analysis: ;ents possess parametric knowledge of this gnal and react to it so that it is reproduced equilibrium. Since m and $\phi(\cdot)$ are thus ıown to agents, observing the price is ıuivalent to an observation on the ratio $/\theta$, provided $\phi(\cdot)$ is a monotone function. he signal z then consists of the event $1/\theta$ ıd the multiplicative noise x.

Let us define a new function

$$\psi(z)=z/\phi(z), \tag{)}$$

[9]This claim is substantiated in Lucas (1972, pp. 1–12). Familiarity with Lucas' important paper will : helpful to the reader but is not taken for granted in hat follows.

and rewrite the market equilibrium condition (3c) in the form

$$y=\psi(z), \tag{6a}$$

which shows how much young individuals work (and produce) at each value of the signal z. Then, recalling that $z=x/\theta$, $z'=x'/\theta'$ and $p'=mx\phi(z')$, we have by definition,

$$\begin{aligned} px'/p' &= m\phi(z)x'/[mx\phi(z')] \\ &= z'\theta'\phi(z)/[z\theta\phi(z')] \\ &= \theta'\psi(z')/[\theta\psi(z)]. \end{aligned} \tag{6b}$$

Substituting (6a) and (6b) into (3b), it is clear that, for all z, the stationary equilibrium output-per-head function, satisfies

$$[\psi(z)]^2=E[(\theta'/\theta)\psi(z')|z]. \tag{7a}$$

The expectation on the right-hand side of equation (7a) is taken over the distribution of θ conditional on z, and over the unconditional probability distributions of x' and θ' that, as future variables, are independent of the current z value. Hence,

$$\begin{aligned} &E[(\theta'/\theta)\psi(z')|z] \\ &\quad = E\left(\frac{1}{\theta}\middle|z\right)E_{\theta',x'}[\theta'\psi(z')]. \end{aligned} \tag{7b}$$

Since the random variables θ and z are stationary, we have $E_{\theta',x'}[\theta'\psi(z')]=E_{\theta,x}[\theta\psi(z)]$, and equation (7a) reduces to

(7c)

$$[\psi(z)]^2=E(\theta^{-1}|z)E_{\theta,x}[\theta\psi(z)],\ \forall z.$$

The second term on the right-hand side of equation (7c) is simply a number; the first term—the expectation of $1/\theta$ conditional on the currently observed value of $z=x/\theta$—is clearly a function of z which can be computed by anyone with an elementary knowledge of probability theory. Since this function is surely positive, let us define

$$[M(z)]^2=E(1/\theta|z). \tag{7d}$$

Under mild restrictions on the probability distributions of x and θ, Lucas (1972, p. 116) shows that the function $M(z)$ is increasing and has an elasticity at most one for all values of z.

Combining (7c) and (7d), one has the following definition.

Definition 1: *Equilibrium is a function* $\psi(z)$ *such that, for all* z:

(i) $p=mz/\psi(z)$;
(ii) $y=\psi(z)$; *and*
(iii) $[\psi(z)]^2=[M(z)]^2E_{\theta,x}[\theta\psi(z)]$.

The symmetric nature of this economy implies that the function $\psi(\cdot)$ characterizes equilibrium in *both* islands: equilibrium price is $mz/\psi(z)$ in Atlantis and $m\hat{z}/\psi(\hat{z})$ in Pacifica, where $\hat{z}=x/(2-\theta)$.

From definition 1, we see immediately that our fictitious economy possesses *two* stochastic steady states:[10] one with $\psi(z)=0$ and $p=\infty$ for all z, that is, with worthless money and no exchange; another with valuable money and some exchange. The latter equilibrium satisfies

$$\psi(z)=kM(z) \tag{8a}$$

where k is defined as

$$k=E_{\theta,x}[\theta M(z)]. \tag{8b}$$

The economy-wide rate of output prevailing in equilibrium depends on the current values of x and θ, viz.,

$$Y(x,\theta)=(1/2)[\theta\psi(z)+(2-\theta)\psi(\hat{z})]. \tag{9}$$

Disregarding in the sequel the steady state associated with infinite price level, define the natural rate as follows.

Definition 2: *The natural rate of output,* $\overline{Y}$, *is the unconditional expectation of the aggregate output function* $Y(x,\theta)$.

[10] These solutions correspond closely to the two steady states which typically appear under perfect foresight in simple versions of the overlapping generations model. See David Gale, Wallace, and David Cass et al.

From (8a), (8b), and (9), we have readily

$$\begin{aligned}\overline{Y}&=(k/2)E_{x,\theta}[\theta M(z)+(2-\theta)M(\hat{z})]\\&=(k/2)E_{x,\theta}[2\theta M(z)]=k^2.\end{aligned} \tag{10}$$

The next section illustrates the nature c equilibrium in four instructive polar cases: is known with certainty in the first case, an price signals do not convey to individual any additional knowledge; in all other case θ is stochastic and information about it realized value is available to individuals onl through the price they observe in their ow island.

II. Some Examples

Example 1 (Certainty): Suppose x is an random variable and $\theta=1$ with probabilit 1, that is, the young are distributed equall over the two markets. Then, for all z, $E(\theta^-$ $z)=1$; $M(z)=1$; $k=1$; and $\psi(z)=1$. Henc $Y(x,1)=1$ for all x; the natural rate is $\overline{Y}_c=1$ and the price level is $p_C=mx$ in each islanc

Despite its simple structure, this exampl has the essence of the classical dichotom property. Nominal changes affect the pric level alone while output is determined b such "real" factors as preferences and tech nology.

Example 2 (Perfectly informative price sig nals): Let us now reverse the randomness c the previous example, assuming that x i deterministic and known while θ is any ran dom variable. Without any further loss c generality, assume $P(x=1)=E\theta=1$.

A price observation here is equivalent t an accurate population census since it reveal the current value of z which everyone can us to guess θ perfectly. Recalling that $z=1/\theta$ we have $E(\theta^{-1}|z)=\theta^{-1}$; $M(z)=\theta^{-1/2}$; an $k=E\theta^{1/2}$. Hence, economy-wide output is

$$Y_I(1,\theta)=(1/2)[\theta^{1/2}+(2-\theta)^{1/2}]E\theta^{1/2}; \tag{11a}$$

he natural rate is

$$\text{(11b)} \qquad \bar{Y}_I = [E\theta^{1/2}]^2 < 1.$$

The inequality in (11b) derives from Jen-ion's inequality applied to the concave func-ion $\theta^{1/2}$. The natural rate of output in this xample is smaller than in the previous one, ut output is again governed entirely by real actors—preferences, technology, and the istribution of suppliers over markets.

Example 3 (Noisy price signals): Suppose hat *both* x and θ are stochastic. In particu-ar, define two positive numbers θ_1, θ_2 such hat $\theta_1 < \theta_2$ and $\theta_1 + \theta_2 = 2$. Assume now that $P(\theta=\theta_1) = P(\theta=\theta_2) = 1/2$; also let $P(x=\theta_1) = P(x=\theta_2) = 1/2$. Then z can attain only hree values: $z_1 = \theta_1/\theta_2$; $z_2 = 1$; and $z_3 = \theta_2/\theta_1$. f $z = z_1$, we know that $P(\theta=\theta_2) = 1$; simi-arly $z = z_3$ implies $P(\theta=\theta_1) = 1$. On the other and, $z = z_2$ implies $P(\theta=\theta_1) = 1/2$ and $P(\theta = \theta_2) = 1/2$. Hence

$$\text{(12a)} \quad M^2(z) = 1/\theta_2 \qquad \text{if } z = z_1;$$
$$= (1/2)(1/\theta_1 + 1/\theta_2) \quad \text{if } z = z_2;$$
$$= 1/\theta_1 \qquad \text{if } z = z_3.$$

$M(z)$ is obviously an increasing function. Continuing, we obtain

$$\text{(12b)} \quad k = E[M(z)]$$
$$= (1/4)\left[\theta_1^{1/2} + \theta_2^{1/2} + 2(\theta_1\theta_2)^{-1/2}\right].$$

The natural rate, as usual, equals k^2, that is,

$$\text{(12c)} \quad \bar{Y}_N = (1/16)\left[2 + 2(\theta_1\theta_2)^{1/2} + 4(\theta_1\theta_2)^{-1} + 4\left(\theta_1^{-1/2} + \theta_2^{-1/2}\right)\right].$$

After some trivial algebra, one shows that $k > 1$ for all θ_1, θ_2 such that $\theta_1 + \theta_2 = 2$. Hence

$$\text{(12d)} \qquad \bar{Y}_N > 1.$$

Example 4 (Totally uninformative price sig-nals): Suppose now that prices convey no information whatever on θ. This will happen if the ratio x/θ is constant or, alternatively, the probability distribution of x contains an "infinite amount" of noise.[11] Then supply decisions are independent of prices and the conditional expectation $E(\theta^{-1}|z)$ simply equals the unconditional expectation $E\theta^{-1}$. It follows that $M^2(z) = E(1/\theta)$ and, since $E\theta = 1$, we have

$$\text{(13a)} \quad k = E_{\theta,x}[\theta M(z)] = [E(1/\theta)]^{1/2}.$$

Individual output is $\psi(z) = kM(z) = E(1/\theta)$ for all z, and so is aggregate output as well. The natural rate is also

$$\text{(13b)} \qquad \bar{Y}_U = k^2 = E(1/\theta).$$

By Jensen's inequality, we derive again, for any probability distribution of θ with mean one, the relation

$$\text{(13c)} \qquad \bar{Y}_U > 1.$$

An immediate corollary of all these examples is that *the average rate* of economic activity does respond in general to monetary forces. The only difference of examples 3 and 4 from example 2 is that the nominal transfer variable x is random in the former two and deterministic in the latter; yet average economic activity may change substantially.

To dramatize this change, assume for all three examples that $P(\theta=0.2) = P(1.8) = 1/2$. Equations (11b), (12c), and (13b) then yield

$$\text{(14)} \quad Y_I = 4/5;\ \bar{Y}_N = 1.64;\ \bar{Y}_U = 25/9.$$

It is not essential at this stage to understand why the addition of noise in the process of money creation can *double* the natural rate from .80 in example 2 to over 1.60 in examples 3 and 4. One does not even have to know why that index of economic activity would increase rather than decrease, as Milton Friedman predicted in his Nobel lecture (1976, p. 464 ff.); as we shall see in Section IV, the direction of this effect de-

[11]An infinite amount of noise is contained, for, instance in Jeffreys' improper prior distribution.

pends on both the ordinal and the cardinal properties of the utility function.

It is important, however, to recognize that the natural rate of output cannot be defined independently of nominal forces, that is, of the probability distribution of money supply, unless θ is deterministic. Indeed, as both θ_1 and θ_2 tend to 1, all three natural rates in equation (14) also tend to 1 and to mutual equality.

III. Is Anticipated Money Neutral?

Classical monetary theory establishes the neutrality of perfectly foreseen changes in the stock of money when these are entirely free from redistributive side effects.[12] Stochastic nominal movements in the economy of Section I are generally not subject to perfect foresight but still preserve, by construction, the existing distribution of nonhuman wealth. Can we conjecture the first sentence of Proposition 1 from the strong classical flavor of this economy? In other words, if we replace the stationary probability distribution of the nominal transfer variable x with another which differs only in expected value, will the same relative prices and allocations prevail in stationary equilibrium?

The answer is clearly in the affirmative when no confusion exists between relative and absolute prices: As long as price signals are clear on this score, all nominal movements are reflected solely in the *level* of prices.[13] Noise in price signals, however, has radical consequences for the neutrality of money. Suppose, for instance, that in example 3, we leave the distribution of θ unchanged but add to x any constant, k, such that

$$(15) \qquad k \neq 0;\ k+\theta_1 > 0.$$

Then we have $P(\theta=\theta_1)=P(\theta=\theta_2)=1/2$; $P(x=k+\theta_1)=P(k+\theta_2)=1/2$. The signal $z=x/\theta$ now attains four *distinct* values, namely

$$(16) \quad z=\{(k+\theta_1)/\theta_2,(k+\theta_2)/\theta_2,$$
$$(k+\theta_1)/\theta_1,(k+\theta_2)/\theta_1\}.$$

Observing the first two of these values means with probability 1, that θ is θ_2; the last two on the other hand, imply $\theta=\theta_1$, again with probability 1. The addition of a constant term to money supply merely alters the mean but still manages, in this case, to dissolve the noise and convert price messages to perfect proxies of the true event, θ. The allocations of example 3 now coincide with those of example 2. I conclude, therefore, that *not all anticipated changes in money stock are neutral.*

The knife-edge property the distribution of x possesses in example 3, is, of course contrived; arbitrary translations in the probability distribution of the nominal disturbance will not generally eliminate signal noise. Smoother distributions for the random variables x and θ, however, cannot restore neutrality to anticipated money, simply because the analog to the classical invariance proposition conjectured at the beginning of this section is false when markets for contingent claims are incomplete.

An intuitive interpretation of why neutrality obtains under perfect foresight must rely on the *deterministic* nature of changes in money supply. Since the stock of money is then just a number, the ratio of any two values of it is also a number, and nominal movements are equivalent to changes in the unit of account.

This argument breaks down, however when money is a random variable. Let x be a nominal transfer variable with a known probability distribution, and define another transfer variable $\omega=T(x)$ where T is an arbitrary single valued function. The probability distribution of ω can be derived easily from that of x, but the ratio ω/x is generally a random variable whose realized value will depend on x. The equivalence between nominal changes and changes in the unit of account vanishes.

[12] Compare Patinkin, ch. 8 and the references he cites in note J.

[13] Compare Lucas (1972, pp. 112–13).

We saw a nonequivalence example in the ›eginning of this section. Let k be a positive ıumber and $T(x)=x+k$. Then the random ariable $\omega/x=1+k/x$ is a monotone func-ion of x. Intuition, nevertheless, suggests hat one particular transformation of x, the cale change $T(x)=\lambda x$ for any $\lambda>0$, should ontinue to be neutral even if x is random. 'he following result follows readily from lefinition 1.[14]

'HEOREM 1: *Let $\psi(x/\theta)$ solve equation* 7a) *and $\tau(\omega/\theta)$ solve the corresponding equa-ion when x is replaced by $\omega=\lambda x$, with $\lambda>0$. 'hen $\tau(\omega/\theta)=\psi(\omega/\lambda\theta)=\psi(x/\theta)$ for all ›ositive (x,θ,λ).*

'or two-parameter probability distributions, ı scale change in money stock is a transfor-nation in which the mean and standard lerivation of x are altered by the same factor n the same direction. The transformation is ıeutral in that it fails to change *any moment* n the probability distribution of the output-›er-head schedule which prevails in sta-ionary equilibrium.

An immediate corollary of Theorem 1 is hat a movement in the expected level alone ›f the nominal disturbance must necessarily ıave the same qualitative effect on equi-ibrium allocations as would a movement of he standard deviation in the *opposite* direc-ion. To see this, let (μ,σ^2) be the first two noments of x, and define ω_1 to be a vari-ınce-preserving transform of x, that is,

$$\omega_1=x+(\lambda-1)\mu,\ \lambda>0 \tag{17}$$

'he variable ω_1 has mean $\lambda\mu$, as does the ω lefined in Theorem 1, and variance σ^2, as loes x. If variance-preserving transforms of ı were neutral, then ω_1 would support in stationary equilibrium the same allocation of resources as does x and, by Theorem 1, the one supported by ω as well. Note that ω_1 shares a common mean with ω but, for any $\lambda\neq1$, has different variance; hence, *if vari-ance-preserving changes in the expected value of money supply were neutral, then mean-preserving changes in the variance of money supply should be neutral as well.*

Examples 2 and 4 of Section II, however, reveal that mean-preserving changes in the variance of the nominal transfer variable are hardly neutral since the expected value of aggregate output is smaller than unity in example 2, greater than unity in example 4.

An entirely symmetric argument should convince the reader that stable feedback rules for money supply are neutral if, and only if, uncontrollable factors enter the process of money creation as multiplicative errors. Specifically, if the stationary, independent random variable ε' represents the future value of such factors, and x' is the future value of the nominal transfer variable, then a necessary and sufficient condition for a feedback rule $F(\cdot)$ to exert no influence on equilibrium relative prices and output in this economy is

$$x'=F(\theta,x)\varepsilon'. \tag{18a}$$

The well-known example by Sargent and Wallace (1975) illustrates the ineffectiveness of rules which satisfy precisely this restriction.

On the other hand, a feedback rule of the form

$$x'=F(\theta,x)+\varepsilon' \tag{18b}$$

is not neutral because the policymakers' "target" value $F(\theta,x)$ will no longer act in the future as a scale factor on the random variable ε'. The choice of $F(\cdot)$ will therefore influence the probability distribution of equilibrium output.

IV. Why Does the Natural Rate Vary?

We saw in Sections II and III that the natural rate of output responds not only to changes in the "real" structure of our fictitious economy but to "nominal" forces as well, that is, to the choice of feedback rule and, more generally, to changes in the stochastic structure of money supply.

[14]Theorem 4 holds quite generally in the stationary state; see Lucas (1972, p. 116).

To understand why this is so, we must review how the money supply process influences the intertemporal terms of trade—that is, the commodity interest rate—which suppliers of goods must take as given in this economy.

We return to Section II and, in order to underline our main point, we pick two extreme cases: perfectly informative price signals from example 2 and totally uninformative signals from example 4. In each case suppliers make an allocative decision with full knowledge of their endowment and of the price ruling in their island, but with incomplete knowledge of the future rate of return on their labor. That rate of return is clearly

$$r = px'/p' - 1 \tag{19a}$$

by equation (3a). We may also interpret the interest factor $1+r$ as a *wage* rate.

Since $p = m\phi(z) = mz/\psi(z)$ by definition 1, and $\psi(z) = kM(z)$ by equation (8a), we have further that $p' = mxz'/\psi(z')$. Hence

$$1 + r = \frac{zx'}{z'x}\frac{M(z')}{M(z)} = \frac{\theta'}{\theta}\frac{M(z')}{M(z)}. \tag{19b}$$

With perfectly informative price signals, the current θ-value is fully revealed, which implies $M^2(z) = E(\theta^{-1}|z) = \theta^{-1}$ and $M(z) = \theta^{-1/2}$. The interest rate becomes a random function of θ, namely

$$r_2(\theta, \theta') = (\theta'/\theta)^{1/2} - 1. \tag{20a}$$

The totally uninformative case of example 4 in Section II, on the other hand, requires that $E(\theta^{-1}|z) = E\theta^{-1}$ and $M(z) = (E\theta^{-1})^{1/2}$. The rate of return on current leisure is

$$r_4(\theta, \theta') = \theta'/\theta - 1, \tag{20b}$$

with both θ and θ' unknown at the time the decision to produce is made.

As we have assumed in equation (2) that suppliers are neutral toward consumption risk, the yield on current leisure influences allocative decisions only through its expectation conditional on current information. Keeping in mind that $E(\theta')^{1/2} = E\theta^{1/2}$, the relevant values are

$$E(r_2|\theta) = \theta^{-1/2}E\theta^{1/2} - 1; \tag{21a}$$

$$Er_4 = E\theta^{-1} - 1. \tag{21b}$$

The θ value revealed in the informative case affects very much the relative size of these conditional expected rates of return and also the relative size of goods supplies in the two cases. However, if all we wish to rank are natural rates of goods supply, we are justified in comparing *unconditional* rates of return, that is, equation (21b) with

$$Er_2 = E\theta^{-1/2}E\theta^{1/2} - 1. \tag{22a}$$

Recall that $\theta^{1/2}$ is a concave function of θ while $\theta^{-1/2}$ is a convex one. By Jensen's inequality, we thus have $E\theta^{1/2} < 1 < E\theta^{-1/2}$. Furthermore

$$\begin{aligned} E\theta^{-1} &= E(\theta^{-1/2})^2 \\ &= (E\theta^{-1/2})^2 + cov\{\theta^{-1/2}, \theta^{-1/2}\} \\ &> (E\theta^{-1/2})^2 > E\theta^{-1/2}E\theta^{1/2}. \end{aligned} \tag{22b}$$

Hence, unconditional expectations satisfy

$$Er_4 > Er_2. \tag{23}$$

We are led to a somewhat paradoxical conclusion: totally uninformative price signals bless the labor of suppliers with a rate of return, or with a wage rate, higher in expected value than would be forthcoming if prices were perfectly informative. In choosing between average work today and average consumption tomorrow, the higher "wage" rate associated with uninformative signals produces a substitution effect which tends to raise today's work and an income effect going in the opposite direction. According to the preference structure of equation (2), consumption and leisure are gross substitutes; the substitution effect of the change in wage rate dominates the income effect, and uninformative prices support on average a larger

low of goods than do perfectly revealing prices. $\bar{Y}_U$ is then greater than $\bar{Y}_I$.

I hasten to add that this outcome is merely an example, not a theorem of any generality. Theoretically, of course, it is just as possible for $\bar{Y}_I$ to exceed Y_U, if consumption and leisure are gross complements, or for the two numbers to bear *any* relationship to each other if the relative sizes of the income and substitution effects alternate over the range of feasible labor supply. For individuals who are averse to risky consumption streams, one has to take into account as well the effect of monetary noise on the *variability* of interest (or wage) rates.[15]

The precise response of the natural rate to monetary "forces" remains unknown pending further theoretical and empirical developments.[16] It is not too early, however, to realize that systematic monetary policy generally does have *some* impact on the natural rate of output, even in market-clearing models of rational expectations, because it influences the average terms of trade between the present and the future.

V. Are Constant Growth Rules Desirable?

The most difficult proposition in what we have named (or perhaps misnamed) natural rate theory still awaits attention, namely, the welfare gains, if any, from eliminating noise in the process of money creation.[17] Abstracting heroically, we may rephrase the question a bit more precisely: Given the "real" structure of the model economy in Section I, would its inhabitants prefer equilibria with noisy price messages (i.e., with stochastic x) to equilibria with clear price messages (i.e., with deterministic x)?

The ultimate aim of monetary policy, that is, of all discretionary elements in the stochastic structure of x, is economic stabilization: to insure the consumption/leisure bundles of individuals facing a shortage of opportunities to insure themselves privately. Our fictitious economy models this shortage in an extreme manner—it contains no markets for contingent claims on consumption.

If monetary policy is to some degree social insurance, then any pair of monetary policies may be ranked in the same way as two alternative insurance policies would be—by comparing the expected utilities that correspond to each of them. Our first order of business is, therefore, to define an expected utility index, and use it to answer the specific question raised at the beginning of this section.

Looking back at equations (8a) and (19b), we see that each person born on Atlantis faces an equilibrium allocation $\{kM(z), k(\theta'/\theta)M(z')\}$, where the first component refers to work in youth and the second to consumption in old age. Similarly, each person born on Pacifica faces the allocation $\{kM(\hat{z}), k(\hat{\theta}'/\hat{\theta})M(\hat{z}')\}$, where $\hat{\theta}=2-\theta$; $\hat{\theta}'=2-\theta'$; $\hat{z}=x/\hat{\theta}$; and $\hat{z}'=x'/\hat{\theta}'$. The expected utility, $H(z)$, of a young person in Atlantica conditional on the price signal received in youth may be computed quite easily, if we recall that $M^2(z)=E(\theta^{-1}|z)$ and $E[\theta M(z)]=k$. Then

$$\begin{aligned}(24a)\quad H(z)&=E_{\theta',x',\theta|z}\left[k(\theta'/\theta)M(z')\right]\\&\quad-(1/2)k^2M^2(z)\\&=kE\left(\theta^{-1}|z\right)E_{\theta',x'}\left[\theta'M(z')\right]\\&\quad-(k^2/2)M^2(z)\\&=k^2M^2(z)-(k^2/2)M^2(z)\\&=(1/2)k^2M^2(z).\end{aligned}$$

Similarly, the corresponding conditional expected utility in Pacifica is

$$(24b)\qquad H(\hat{z})=(1/2)k^2M^2(\hat{z}).$$

Because θ has a symmetric distribution, the unconditional expected utility in either is-

[15]Agnar Sandmo, and Michael Rothschild and Joseph Stiglitz investigate in influence on saving decisions of changes in the riskiness of interest rates.

[16]A beginning on the empirical side is made in Donald Mullineaux.

[17]These rules evoke the name of Friedman (1948, 1968). An earlier, and more reluctant, advocate of constant growth rules for money supply was Simons (1948).

land is

$$(24c)\quad \bar{H}=(1/2)k^2E[M^2(z)]$$
$$=(1/2)k^2E_zE(\theta^{-1}|z)$$
$$=(1/2)k^2E(\theta^{-1})=(1/2)\bar{Y}E(\theta^{-1})$$

where $\bar{Y}=k^2$ is, by equation (10), the relevant natural rate.

Again, let us confine our attention to the polar cases of examples 2 and 4 of Section II and not attempt to identify an "optimal" monetary rule. When money and price signals are perfectly informative, we recall that $z=1/\theta=M^2(z)$ and $k=E\theta^{1/2}$. Conditional expected utilities are

$$(25)\quad H_2(\theta)=(1/2\theta)E^2(\theta^{1/2});$$
$$H_2(2-\theta)=[1/(2-2\theta)]E^2(\theta^{1/2}).$$

If, on the other hand, money and prices are totally uninformative, then the conditional and unconditional expected utilities coincide and are equal to

$$(26)\quad H_4=(1/2)k^2E\theta^{-1}=(1/2)E^2(\theta^{-1})$$

in each island.

One way to rank a perfectly informative monetary policy relative to a totally uninformative one is to ask which makes *all* young agents no worse off in *all* states of nature, and better off in some state. More formally, we have

Definition 3: *A perfectly informative monetary policy is* superior *to a totally uninformative policy if, for all θ in $[A, B]$,*

$$(27a)\quad h_2(\theta)\geqslant H_4 \text{ and } H_2(2-\theta)\geqslant H_4,$$

with at least one strict inequality for some θ; it is inferior if, for all θ again,

$$(27b)\quad H_2(\theta)\leqslant H_4 \text{ and } H_2(2-\theta)\leqslant H_4,$$

with at least one strict inequality for some θ.

One sees immediately from equations (25) and (26) that (27a) cannot hold for any θ, as it implies $E\theta^{1/2}>E\theta^{-1}$, a contradiction of Jensen's inequality. Conversely, (27b) holds if, and only if, θ is distributed in a narrow enough interval around unity. Specifically, if we define $\beta=E\theta^{1/2}/E\theta^{-1}$, inequality (27b) is equivalent to

$$(28)\qquad \beta^2\leqslant\theta\leqslant 2-\beta^2,\ \forall\theta.$$

Unless we impose further restrictions on the probability distribution of θ, we shall find ourselves unable to compare two *diametrically opposed* monetary policies, to say nothing of ranking policies which differ only slightly. To avoid this quandary, I propose to weaken definition 3 and evaluate allocations by the unconditional (lifetime) utility young persons associate with them.[18]

Definition 4: *A perfectly informative monetary policy is superior to a totally uninformative policy if $E_\theta[H_2(\theta)]>H_4$, inferior if $E_\theta[H_2(\theta)]<H_4$.*

The uninformative policy is clearly dominant on this definition: it corresponds to a higher natural rate of output and, by equation (24c), to higher unconditional expected utility as well.

Our impartial observer may be suspicious that definition 4 is less appropriate than definition 3 as a device to rank monetary policies: after all, people are assigned to an island at the beginning of their lives and the realized value of θ is, so to speak, on their birth certificate, even if they cannot directly read it. How can these people form expectations of utility unconditional on θ?

The answer is rather obvious. We can postulate that each generation ranks monetary policies before it observes the price signal in its youth. Or else, we may amend the model slightly in the following way: individuals live now for *three* periods, adolescence, youth, and old age. The last two periods are specified exactly as in Section I. Adolescence, on

[18]These and other related criteria are discussed in the interchange between H. M. Polemarchakis and L. Weiss and Lucas (1977). The former authors were the first, to my knowledge, who discovered that constant growth rules were suboptimal in the Lucas model.

the other hand, occurs before individuals receive their island assignment; it is a period of economic inactivity and quiet rumination about lifetime expected utilities and monetary policy!

I conclude from this discussion that, in our general equilibrium model with rational expectations, such perfectly informative monetary policies as constant growth rules are not necessarily superior to totally uninformative policies, and certainly not "optimal" in any transparent sense.[19]

The opposite view, most forcefully expressed in Barro (1976, pp. 15–19), proposes in principle to purge the economy of nominal disturbances on the grounds that doing so would convey to citizens as much "information" about the true state of nature θ as is feasible under prevailing market arrangements. Since θ is inherently stochastic, the "amount" of information on θ transmitted by this action would naturally fall somewhat short of perfect foresight but, in some sense, would still partly relieve informational distortions.

Despite its intuitive appeal, this informational argument is somewhat circular because one *defines* changes in the available amount of economically useful information by their effect on expected utility.[20] But the real weakness of the information story lies in the theoretical framework in which it is imbedded. The general equilibrium model of rational expectations we have used throughout this essay possesses, in my opinion, a major structural inconsistency: it fails to explain what conceivable factors (for example, transactions costs or private information) ought to be blamed for the complete absence of private insurance markets in our fictitious economy. In other words, why is it impossible for individuals to exchange forward contracts or consumption claims contingent on available information?

The model of Lucas is then a second best construct with a somewhat arbitrary market structure; it is no surprise that, in it, the piecemeal removal of informational distortions does not necessarily contribute to welfare because it involves a "pathological" change rather than a simple expansion of opportunity sets. In fact, recent work by O. D. Hart and by Green and Sheshinski leads us to *expect* such behavior from second best models in which market structure is fixed arbitrarily.

VI. Conclusions

The examples of Sections II–V suggest that the principal conjectures of neoclassical macroeconomics considerably overstate the neutrality properties which money and monetary policy possess in the general equilibrium model of rational expectations due to Lucas.

Classical invariance properties of money known to obtain under perfect foresight (A. C. Pigou) continue to hold under uncertainty in modified form: *scale* changes in money supply leave relative prices and quantities unchanged in equilibrium. But there is no good reason why monetary policies should normally affect the stock of money in this wonderfully simple, multiplicative manner and, therefore, no reason why monetary rules should generally be neutral. By the same token, any nonscale change in the aggregate nominal disturbance will have real consequences somewhere in the economy.

Equally exaggerated is the reputation of the natural rate of output (or unemployment) as a proxy for average economic activity which remains invariant to nominal forces and, by extension, to an unspecified range of aggregate demand tools.

Whatever the measure of employment one chooses, it is bound to respond systematically to nominal forces in general, and policy rules in particular, for the same reason similar measures of saving would: money has the power to alter the probability distribution of the terms of trade between the present and the future (equivalently the real future yield

[19]Peter Diamond, and Jerry Green and Eytan Sheshinski discuss restricted concepts of optimality.

[20]The alternative is to define a priori a statistical, as opposed to economic, measure (for example, entropy, variance) of the information contained in a stationary price distribution; it is easy to show by example (see Rothschild-Stiglitz, pp. 242; Gould) that expected utility isn't always a monotone function of such information measures. Statistical definitions of informational content are discussed in Henri Theil, ch. 12 and, in more detail, in S. Kullback, chs. 1 and 2.

on current labor) and thereby to influence *all* decisions in whatever direction agents' preferences dictate.

The model of Lucas, described in Section I, offers little succor to the view that a policy of constant growth for money supply is optimal. No rule in this model can remove *all* informational imperfections that is, endow agents with perfect foresight; and no rule is equivalent to opening *all* the markets missing from the model. Constant growth rules here are akin to a partial removal of (informational) imperfections in a second best world. The theory of second best implies, however, that piecemeal policies do not always improve existing allocations and, hence, that k percent rules cannot generally dominate other stationary rules for money supply.

Whether such an agnostic view of neoclassical macroeconomics is warranted depends to some degree on how useful one finds the underlying formal apparatus. Have we reached negative conclusions because the conjectures we tested were false, or because the particular model we employed did not provide a fair proving ground?

That is a difficult question, the answer to which I can only guess imperfectly. Having gone through all the counterexamples in this essay, I find it rather difficult to imagine how *every* anticipated change in money supply must be neutral in an economy with incomplete claims markets, or how the natural rate of output can be immune to *every* systematic change in monetary policy.

Conjectures like Propositions 1 and 2 stated earlier can hardly be meant as solid pieces of economic theorizing; to me, at least, they seem to be intended primarily as a protest against the omnipotence aggregate demand policy tools have long possessed in orthodox Keynesian macroeconomics. Some of these tools are emasculated in Proposition 1, as they would be in the ordinary *IS-LM* framework, by an aggregate supply schedule that is strictly price invariant; others are neutralized in Proposition 2 by an aggregate supply schedule that is price invariant on average.

On the other hand, I suspect that the rational expectations framework we have used is not well suited to examining the welfare properties of monetary policies, for it does not pay sufficient attention to the existence (or nonexistence) of those private insurance markets that stabilization policy is supposed to be supplementing.

Our impartial observer will not take very seriously the example of Section V in which a constant growth rule is worse than a "totally random" monetary policy. There are many attractive features in predictable money supply that the fictitious economy of this essay has not done justice to; one of them is that forward contracts on goods and services (especially nominal contracts on some capital goods and most labor services) typically become much more attractive insurance policies when money supply is predictable, and extremely risky when monetary policy is capricious.

To sum up: My reexamination of the central conjectures of natural rate theory offers no definitive proof that some of them are necessarily "false"; they may well be "true" in an economy with highly developed securities markets. I hope, however, enough evidence is contained herein to persuade impartial observers that fanciful statements such as "the economy always floats back to its natural rate," or "feedback rules are ineffective," or "anticipated money is neutral" are not predictions of any *known* neoclassical macroeconomic model of general equilibrium. These statements, popular though they are at present, have a precarious microeconomic foundation; to use them as working hypotheses is unlikely to advance our understanding of stabilization policy issues much further than *IS-LM* analysis did a generation ago.

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Perceived and Expected Rates of Inflation in Sweden

By LARS JONUNG*

The perceived rate of inflation, that is, the public's knowledge about the historical behavior of the price level, plays an extremely important—although little observed—role in much of recent work on the formation of inflationary expectations. As a rule, economists have used past (weighted) inflation rates to construct proxy measures for the expected rate. This common approach proceeds as if all relevant economic units have the same perceptions of past inflation rates and as if perceived rates are identical to actually registered historical rates. Empirical evidence on this issue is examined here using results from a survey study of perceived and expected inflation rates in Sweden.

The desire to include inflationary expectations in empirical studies has resulted in a number of attempts to measure prevailing expectations directly. These direct measures have been of two types, both of which utilize data from survey studies. The first is based on surveys where respondents state whether they expect prices to rise, stay constant or fall. The qualitative replies are then transformed into quantitative series to be used in econometric studies.[1] See, for example, the work by George de Menil and Surjit Bhalla for the United States, John Carlson and Michael Parkin for the United Kingdom, Adalbert Knöbl for Germany, and Michael Danes for Australia.

The second type of measure of inflationary expectations is based on surveys which ask for direct quantitative measures of expected changes in prices. The best known among these is probably the Livingston series for the United States.[2] The Livingston series, however, encompasses a small number of respondents, all with a background of business experience. Various series of expectations have been gathered covering more representative samples of the general public. The Survey Research Center (*SRC*) in Michigan is producing such data for the United States. This kind of direct measure should provide better answers to questions concerning the public's inflationary expectations than the Livingston data or similar series covering specific groups in society.

This paper describes a survey of perceived and expected rates of inflation in Sweden that belongs to the second category of studies described above. In the literature on inflationary expectations, this Swedish investigation stands out in two respects. First, the respondents are asked about their perceived rates of past inflation as well as about their expectations of future inflation rates. Secondly, responses are cross-classified by demographic characteristics such as sex and age. The survey covers a broad representative national sample of about 10,000 Swedish households, encompassing roughly 0.3 percent of the total of 3.5 million Swedish households. This makes detailed analysis by various cohorts possible.

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[1]The technique adopted for this transformation assumes that the distribution of expectations is characterized by a two-parameter distribution, typically by the normal distribution.

[2]A detailed description of the Livingston data is given by Carlson (1977). This body of data has been used by a number of researchers. See for example Stephen Turnovsky, William Gibson, and David Pyle. See also Paul Wachtel (1977a) for a discussion of various survey measures of inflationary expectations.

I. The Role of the Perceived Rate of Inflation

The basic idea underlying theoretical and empirical studies on the autoregressive formation of inflationary expectations—that is, adaptive expectations and extrapolative/regressive schemes—is that the past history of the rate of inflation is the key determinant of the anticipated rate of inflation. These studies proceed as if the history of inflation is perfectly and uniformly known to the public so that perceived rates are identical to actual rates, typically as expressed by some official index. The standard econometric approach where lagged (past) inflation rates are included as measures of the anticipated rate of inflation is consistent with the twin assumptions that (a) all economic agents hold identical and "true" point estimates of past rates of inflation, and (b) that all economic agents arrive at the same expected future rate of inflation.[3] These assumptions, which are rarely questioned, also characterize much of the empirical work on rational expectations.

Survey studies of direct measures of inflationary expectations show clearly, however, that respondents do not hold uniform expectations; on the contrary the dispersion of anticipated rates appears to be considerable.[4] This finding has induced some researchers to suggest that the dispersion of the replies around the mean expected value should be analyzed as a separate, and potentially important, variable in both empirical and theoretical work. See, for example, Paul Wachtel (1977a). A few attempts in this direction have also been made.[5]

While the potential significance of the distribution of *expected* rates of inflation has been noted in the literature, the distribution of the *perceived* rate of inflation has not yet been studied. Studies of the formation of inflationary expectations that utilize survey data—the very same data which show wide divergencies in expected inflation rates as well as persistent differences between expected and actual rates—have actually adopted historical inflation rates as explanatory variables as if these rates were perfectly and uniformly perceived. Higher moments than the mean are thus assumed to be of no significance for the analysis. See, for example, Turnovsky, and L. V. Defris and R. A. Williams.

This approach is open to objection since survey studies have established that expected rates diverge across respondents. Hence, one should expect perceived rates to diverge as well. Studies of the distribution of actual inflation rates across households also show that economic units experience different rates of inflation due to differences in consumption patterns and relative price changes. See, for example, Bengt Assarsson (1977) for Sweden and R. T. Michael for the United States. This suggests that expected rates differ, partially as a consequence of a dispersion of perceived rates and partially as a consequence of genuine uncertainty about the future behavior of prices.

Moreover, little is known about the process forming the public's perceptions of past rates of inflation. Presumably this process utilizes two sets of data: (a) the public's recollection of price indices, collected and published primarily by government agencies, and (b) the individual's own experience of surveying prices and purchasing goods and services. To the extent that perceived rates are based on official data, a tight distribution of perceived rates should be expected. To the extent that consumption patterns, that is, expenditure shares, differ across individuals, and that perceptions are based on individual price indices, a wide distribution should be expected, *ceteris paribus*. Empirical studies of the formation of inflationary perceptions, however, are presently lacking.[6]

[3]See David Laidler and Parkin (p. 770) for a discussion of this point. Their comments concerning expected inflation rates apply to perceived inflation rates as well.

[4]See, for example, Carlson (1977) and F. T. Juster and R. Comment.

[5]Alex Cukierman and Wachtel have developed a theory which deals explicitly with the distribution of inflationary expectations.

[6]On this point see also Carlson (1980) and Carl Van Duyne. Moreover, the process of generating perceptions of past inflation rates should be influenced by the relative costs and benefits of improving the accuracy of the perceived rates. On this argument see, inter alia, the discussion by Michael Darby and by Edgar Feige and Douglas Pearce of the generation of expectations under costly information.

II. The Empirical Picture

The Swedish survey reported here attempted to obtain a cross-section picture of perceived and expected rates of inflation at a given point of time.[7] A representative sample of households was asked about the movements of "prices in general" during the past twelve months and about expected movements in the coming twelve months.[8] The respondents could answer either with a single number or with an interval. About 4,000 replies of the first type were received and 2,000 of the second.[9] The replies concerning the notions of price level movements were grouped according to the following characteristics: sex, age, income, place of residence, number of children, and type of housing.

These groupings revealed some noteworthy patterns. With respect to the perceived rate, the major difference was found between men and women. For men who gave point estimates of what the 1977 inflation rate had been, the mean was 13.8 percent, while for women it was 15.5 percent. (See Table 1.) This pattern — which holds throughout all groupings of men and women according to age, household income, number of children and place of living—is most easily explained by a larger rise in food prices than in the consumer price level. The official figures were 16.7 percent and 14.2 percent, respectively, in 1977, the period covered by the question about the perceived rate. (See Table 1.)

As women are responsible for the major share of the food purchases within Swedish households,[10] they are more exposed to movements in food prices than men. Consequently, the inflation rates perceived by women should be more strongly influenced by food prices than the rates perceived by men. The difference between men and women apparently indicates that perceived rates are influenced by individual price calculations based on individual expenditure patterns.[11]

The average perceived rate for the whole sample, however, was 14.7 percent which is fairly close to the actual rise of 14.2 in the consumer price index in 1977. Other groupings according to age, household income,

[7]The survey was carried out as part of a government investigation of the effects of price controls in Sweden in the 1970's. A complete description of the survey, published in Swedish as ch. 3 in *Prisreglering mot inflation*? (*Price Controls against Inflation*?). *SOU* (*Government Report*)*1981:41*, is available from the author on request.

[8]The survey was conducted by phone during two weeks in January 1978 by the National Central Bureau of Statistics. The perceived rate thus refers to the inflation of 1977 and the expected rate to the inflation of 1978. The questions about price movements were presented according to a two-stage procedure. First, the respondents were asked whether "prices in general" had fallen, remained unchanged or increased. (A corresponding framing of the question was used for the expected rate.) Second, a percentage estimate was asked for. Thus, the survey questions were open-ended.

[9]There was a considerable group of "don't know" answers. They represented about 20 percent of all replies concerning the perceived as well as the expected rate. The nonresponse rate was 17.5 percent, primarily due to refusal to take part in the interviews. A nonresponse rate of this magnitude is common in this type of survey.

[10]One recent study of the distribution of domestic work between men and women married or living together shows that the woman alone made all or almost all of the daily purchases of food and other items in 53 percent of 4,600 couples interviewed in 1975. The corresponding figure for men was 10 percent. In 84 percent of the couples the woman was responsible for half or more of the daily purchases. (See Table 5.1 in *Living Conditions. Report no 20. Sex and Equality*. Official Statistics of Sweden, Stockholm 1980.)

Another investigation reveals that in 1974 Swedish women were solely responsible for more than 60 percent of all daily purchases measured in terms of volume, of frequency and of value while men alone were responsible for only 21 percent. (See *Samhället och distributionen* (*Society and the Distribution of Goods and Services*). *SOU* (*Government Report*) *1975:69*, p. 150.) It is safe to conclude that these patterns also held in 1977–78 when the survey of inflationary perceptions and expectations reported here was made.

[11]Van Duyne examines whether expectations in the United States are "biased" in the sense that economic agents "place more weight on the recent behavior of food prices than expenditure shares would indicate" (p. 7). He found no evidence of such a bias. His data, however, do not permit him to distinguish between men and women in his study. The significant difference between men and women in Sweden does not necessarily imply biased perceptions. Rather, the pattern in Table 1 is consistent with the view that perceptions are based on expenditure shares which differ between men and women.

TABLE 1—PERCEIVED, EXPECTED, AND ACTUAL INFLATION RATES IN SWEDEN, 1977–78
(Annual Percentage Change)

Perceived Rates for 1977:		Actual Rate for 1977:		Expected Rates for 1978:		Actual Rate for 1978:
Men	Women	Consumer Prices	Food Prices	Men	Women	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
13.8	15.5	14.2	16.7	10.6	11.4	5.9
(5.65)	(8.58)			(5.00)	(6.65)	
Number of replies:						
2,392	1,855			2,375	1,812	

Notes: Standard deviations are shown in parentheses. The rates in columns (1)-(2) and (5)-(6) represent the mean values of approximately 4,200 responses giving a point estimate in the range of 1–50 annual percentage change in prices. The survey was conducted in January 1978. Thus, the rate of change in the consumer price index and in the food price index is calculated from January to January the following year.

The differences between the mean perceived and expected rates of men and women are significantly different at the .01 percent level.

number of children, type of housing, and place of residence did not reveal any pronounced dissimilarities in the perceived rate, although such may have been expected, inter alia, due to differences in relative price changes caused by the Swedish system of taxes and subsidies.[12]

With respect to the expected rate, the major difference relates to age. The expected rate falls fairly linearly with rising age by an average of .4 percentage points for every ten years. The youngest group, those of 18–24 years, expected inflation to be 11.5 percent while the oldest group, those of 70–74 years, anticipated that it would be 9.5 percent. One hypothesis to account for this pattern—which holds for all groups examined—is that the price level history experienced by the respondents influences their expectations of future inflation. The older age groups remember the falling or fairly stable prices of the 1920's, 1930's, and 1940's. This tends to lower their inflationary expectations. The younger respondents, on the other hand, have only experienced the steadily rising inflation rates of the 1950's, 1960's, and 1970's, which raises their inflationary expectations as compared to older generations.

This picture suggests that inflationary expectations are influenced by past experience and observations of inflation, that is, by an autoregressive process which covers not only the most recent years but also the whole lifetime experience of price level movements.[13] However, it should be stressed that there are hardly any differences across age groups in the perceived rate of inflation. This indicates that roughly the same set of price information is available to every age group, which results in fairly uniformly perceived rates, with the exception of the difference between men and women.

With the exception of age, none of the groupings reveal any striking differences concerning the expected rates. On average, women and households with children expect a higher rate of inflation than men and households without children. These differences are less than one percentage point, but are significant at the .01 level. There is also a weak tendency for higher income groups to have higher than average expecta-

[12]The extensive Swedish system of taxes and subsidies has created significant differences in relative prices across households depending on such factors as the choice of housing, income, number of children, region of settlement, and availability of nontaxed consumption goods. See also Assarsson (1977). Such tax- and subsidy-induced relative price differences do not seem to have exerted a significant influence on perceived rates, however.

[13]As the survey is a cross-section study, it does not allow any direct tests of the dynamic generation of inflationary expectations.

TABLE 2—THE EXPECTED INFLATION RATE AS A FUNCTION OF THE PERCEIVED RATE OF INFLATION, AGE, SEX, AND INCOME

	Type of Replies					
Independent Variable	I (1)	II (2)	III (3)	I (4)	II (5)	III (6)
Perceived Rate of Inflation	0.447[b] (0.010)	0.519[b] (0.020)	0.446[b] (0.013)	0.445[b] (0.010)	0.517[b] (0.020)	0.443[b] (0.013)
Age				−0.049[b] (0.004)	−0.053[b] (0.007)	−0.045[b] (0.006)
Dummy variables for:						
Sex (1 if female)				−0.020 (0.130)	−0.226 (0.227)	−0.010 (0.189)
Income						
(1 if middle income)				0.019 (0.152)	−0.074 (0.259)	0.049 (0.222)
(1 if upper income)				0.381[a] (0.156)	0.221 (0.273)	0.437 (0.228)
Intercept	3.656	3.621	3.702	5.625	5.902	5.510
S.E.E.	4.978	3.689	5.375	4.924	3.612	5.332
R^2, Adjusted	0.254	0.371	0.250	0.270	0.397	0.262
Number of replies	6,019	1,101	3,309	6,019	1,101	3,309

Notes: Standard errors are shown in parentheses. The replies are divided into three groups: (I) all answers; (II) answers for the perceived and the expected rate given only with an interval (where the average of the upper and lower limit is taken as the valid observation); and (III) answers given with one number for the perceived and the expected rate. Replies suggesting an expected rate of inflation in the range of 1–50 percent are covered. In this way an extremely small number of replies suggesting a rate of inflation between 50 and 100 percent are excluded as "atypical." Their exclusion, however, does not influence the regression results. The age variable ranges from 18 to 74 years.

The income of the households covered by the interviews are grouped into three categories: lower income (50,000 *kronor* or less), middle income (50,000–80,000 *kronor*) and upper income (more than 80,000 *kronor*) as annual income per household. (1000 *kronor* are roughly equal to $440.)

[a]Statistically significant at the 95 percent level.

[b]Statistically significant at the 99 percent level.

tions.[14] The average expected rate for 1978 was, however, far from the actual rate compared to the small difference between the perceived and actual rate for 1977.[15]

The findings above suggest further exploration of the data by way of a number of regression equations using dummy variables to investigate the role of demographic variables such as sex and age, as well as of income, in determining perceived and expected inflation rates. First, the perceived rate is estimated as a function of sex, age, and income, where the incomes of the responding households are grouped into three classes: low, middle, and high income. The regression estimates, not reported here, show that the dummy variable for sex is the only independent variable significantly different from zero, confirming what was found in pairwise comparisons.

Next, the expected rate is regressed on the perceived rate. This represents a departure from the standard approach of using the actual registered rate(s) as the explanatory variable in econometric work on inflationary expectations. The estimates in Table 2 show that the coefficients of the perceived rate are significantly different from zero and have the expected positive sign for all groupings of

[14]The replies giving single numerical estimates of perceived and expected inflation rates have been analyzed here. The patterns produced by the answers presenting upper and lower boundaries for perceived and anticipated rates are close to the patterns of the point estimates.

[15]Following a few years of continuous increase, the Swedish rate of inflation peaked in January 1978—the same month as the survey was conducted. The rate then fell from 14.2 percent to a low of 5.6 percent for February 1979, calculated as the month-to-month change on a yearly basis. The respondents thus expected correctly a decline during 1978 in the rate of inflation compared to the actual rate during 1977.

replies in columns (1)-(3). When sex, income, and age are included as additional independent variables, several results emerge. (See columns (4)-(6) in Table 2.) The dummy variable for sex becomes insignificant. The dummy variables for income are also insignificant with one exception in column (4) in Table 2. Age, however, is a strongly significant variable showing that for every year of age the expected rates fall by about .05 percentage points. The adjusted R^2s increase marginally in columns (4)-(6) suggesting that the demographic variables and the income variable add little to the explanatory power of the perceived rate. It is reasonable to assume that the age variable reflects the respondents' lifetime experience of price level movements. In that case, the results indicate that expectations are significantly influenced by the past history of prices as measured by age as well as by perceived rates.

The dispersion of inflationary expectations, as represented by the standard deviation or the variance, has attracted considerable interest in recent work.[16] The standard deviation has been adopted as a proxy measure of "uncertainty" concerning the future behavior of prices in some econometric studies.[17] The dispersion of the rates for men and women displayed in Table 1 shows that the coefficient of variation, that is, the standard deviation divided by the mean, is practically the same for perceived and expected rates for both men and women. Table 1 also shows that the respondents are as uncertain about past rates of inflation as about future rates when the coefficient of variation is chosen as a proxy for uncertainty. The same conclusion is obtained if uncertainty is measured by the ratio of "don't know" answers to the total number of interviews. This share was 20.5 percent for the perceived rate and 19.9 percent for the expected rates. Surprisingly, the respondents are as uncertain about the im mediate past pattern of price changes a about future ones according to this measure One would have expected them to be mor informed about recent past events than abou the future.

The dispersion of the perceptions of pas and future inflation rates does not simpl measure uncertainty, however. Relative price do not change uniformly and consumptio patterns differ across households. Conse quently, relative price variability should con tribute to differences in perceived rates—an through perceived rates—to differences i expected rates. Recent studies on relativ price variability—see, for example, R. W Parks for the United States and Assarsso (1980) for Sweden—suggest that relativ price variability covaries positively with th rate of inflation. A higher rate of inflatio with a concomitant wider dispersion of rela tive price changes should, thus, tend to in crease the dispersion of perceived rates. Th survey does not provide any direct evidenc on this hypothesis, however.

The standard deviation of perceived rate in Table 1 may be compared with the relativ price change variability in 1977. Two sugges tive measures are available. First, the stan dard deviation of the relative price change for the six major components constituting the Swedish consumer price index is 3.64 percentage points in 1977. Second, the standard deviation for all 333 goods (unweighted) represented in the consumer price index for 1977 in column (3) in Table 1 is 7.94 percentage points.[18] A study of the variations in inflation rates among the households included in the survey could be helpful in separating the effect of uncertainty on the dispersion of perceived rates from the influence of relative price variability. Such a study has not been undertaken, however.

[16]The distribution of price expectations has been an issue of considerable discussion. The basic question has dealt with the normality assumption underlying the transformation of qualitative survey data to quantitative measures. See fn. 1. Tests (not reported here) show that the distribution of perceived rates as well as of expected rates are *not* normally distributed. The distribution of the perceived and expected rates for men and women also differ significantly.

[17]See Defris and Williams as well as Wachtel (1977b).

[18]The first measure of relative price dispersion is calculated as $[\Sigma w_i \cdot (Dp_i - DP)^2]^{1/2}$ where DP is the percentage change in the consumer price level in 1977, Dp_i is the percentage change in the price of composite commodity i, and w_i is the respective weight in the consumer price index. Six such commodity groups constitute the Swedish consumer price index. The second measure is calculated as $[\Sigma(Dp_i - DP)^2]^{1/2}/n$ where Dp_i is the percentage change in the price of commodity i in 1977.

Still, it seems reasonable to conclude that the dispersion of perceived rates and, thus, of expected rates is influenced by relative price variability as well as by uncertainty.[19]

III. Summary

Four basic conclusions emerge from the empirical results reported here. First, perceived rates exert a strong positive influence on expected rates. Second, demographic characteristics, in this case, sex and age, are significantly related to perceptions and expectations of inflation. With respect to sex, perceived rates differ but expected rates are considerably closer. Women perceived, on average, a higher rate of inflation than men. Food prices rose more rapidly than prices in general during the year prior to the survey. As women are responsible for the major share of food purchases, they should be more strongly influenced by food prices than men. This combination of differences in relative price movements and differences in purchasing patterns probably accounts for the male-female difference in perceived rates. With respect to age, perceived rates are the same but expected rates differ, declining with growing age. A possible explanation of this pattern is that the perceived history of inflation influences expected rates. Older respondents have experienced the low rates of inflation during the 1940's and 1950's. This tends to lower their expectations compared to those of younger respondents who only recollect the fairly high rates of inflation of the 1960's and 1970's.

Sex and age help explain perceived and expected inflation, respectively, because individuals draw upon their personal past experience of changes in prices, that is, they consider the history of the purchasing power of money over their own preferred baskets of goods and services. Individual experience is, thus, an important determinant of inflationary perceptions and expectations.

Third, perceived rates clearly differ across individuals—a conclusion that is consistent with existing evidence on the dispersion of relative price changes and on the dispersion of inflationary expectations. This suggests that the spread of expected rates may be regarded as a function of the dispersion of perceived rates. Fourth, uncertainty—measured either by the coefficient of variation or by the ratio of "don't know" answers to the total volume of responses—about past inflation rates appears to be of roughly the same magnitude as uncertainty about future inflation rates.

[19]Uncertainty about price level movements—and thus the dispersion of perceived and expected inflation—is probably strongly related to the monetary regime prevailing. A monetary standard producing considerable price level predictability should be associated with a tight distribution of inflationary perceptions and expectations, *ceteris paribus*. Recent proposals for monetary constitutions are generally based on arguments emphasizing the benefits of reduced price level uncertainty. On this point see, for example, Benjamin Klein and Axel Leijonhufvud.

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Unemployment and Real Interest Rates: Econometric Testing of Inflation Neutrality

By RICHARD STARTZ*

The resurgent neoclassical school in macroeconomics has, in its simpler characterizations, asserted three hypotheses about the economy. First, the short-run expectations-augmented Phillips curve is vertical. Second, the real rate of interest is independent of anticipated inflation. Third, expectations are formed rationally in the sense that people use mathematical expectations conditional on available information. The three propositions together suggest the neutrality of the economy with respect to anticipated inflation. In this paper I propose a set of regression-based econometric tests of these three neutrality propositions. I carry out simple versions of these tests for the postwar American economy.

Such neutrality propositions distinguish the modern neoclassical school from the traditional American Keynes-Hicks school of macroeconomics. It is true that these statements significantly oversimplify the position of the neoclassical school (sometimes called the rational expectations school) and also true that the traditional school today would mostly accept these propositions in the "long run." However, the argument between the two schools does not rest on minor failures of neutrality, but turns rather on different interpretations of gross gyrations of interest rates and unemployment. By careful testing of simple statements of the neutrality hypothesis it is possible to discover whether empirical evidence is closer to confirming or contradicting the view of the modern neoclassical school.

The arguments develop as follows. First, I explicitly define the null hypothesis so as to state precisely what is to be tested. Second, I derive a proper econometric test and compare it to the classic Fama (1975) tests. Third, I test for neutrality of the postwar American economy. Fourth, I extend both the principles and execution of the tests to consider the case in which unemployment persists due to long-term nominal contracts.

The conclusion from the empirical evidence is the strong rejection of the neutrality hypothesis. The simple characterizations of the neoclassical school cannot stand in light of the empirical evidence. The lesson from the evidence is that if we wish to find a neoclassical, non-Keynesian, model of the American economy, it must be one that supports very large deviations from neutrality.

I. Statement of the Neutrality Hypothesis

Three statements taken jointly form the null hypothesis:

1. The expected real interest rate is independent of the expected inflation rate.
2. Deviations of the unemployment rate from the natural rate of unemployment are associated only with unanticipated inflation.
3. Expectations are rational.

"Rational" expectations are taken to mean that the anticipated value of a variable is its mathematical expectation conditional upon available information. Under rational expectations, the actual inflation rate can be divided into a component of expected inflation and an expectational error, these being mutually independent.

If we denote the nominal interest rate and expected real interest rate by R and r, and inflation[1] and anticipated inflation by π and

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[1]As Eugene Fama points out, we are actually interested in the change in the purchasing power of money. The inflation rate is actually measured as the negative of the deflation rate, throughout. The term "real interest rate" means the *expected* real interest rate, not the *ex post* real interest rate.

π^e, the Fisher equation is

$$(1) \qquad R=r+\pi^e.$$

The fundamental hypothesis about financial markets is that the real interest rate is independent of expected inflation. This premise is not a necessary implication of rational behavior, since almost any model recognizes that real effects may be associated with anticipated inflation, including taxation effects, changes in the opportunity cost of non-interest-bearing real balances, changes in real portfolio demand due to shocks to the marginal product of capital, and changes in risk premia due to contemporaneous changes in the level of and uncertainty about the rate of inflation. Nonetheless, it has been argued that the independence of the real interest rate and expected inflation is an empirically reasonable characterization of the economy. Under the null hypothesis we should find (where σ is the covariance operator): $\sigma_{r,\pi^e}=0$.

In real markets, the neutrality hypothesis appears as the expectations-augmented, or accelerationist, Phillips curve.[2] Deviations of unemployment u from the natural rate u^*, or deviations of actual from potential *GNP*, are associated only with unanticipated inflation. Written most simply this hypothesis becomes

$$(2) \qquad \pi=\pi^e+\beta\hat{u}$$

where $\qquad \hat{u}=u^*-u.$

Implicit in this equation are several restrictions which are not required solely by axioms of rational behavior. The Phillips curve above is linear though most observers suggest that the curve is truly curved. A one-sector world is pictured; as footnote 6 discusses, this is not an innocuous assumption. The basic hypothesis on the Phillips curve is that deviations from the natural rate of unemployment result only from unanticipated events. Since both the expected real interest rate and expected inflation are known to agents when contracts are drawn, we should find $\sigma_{\hat{u},\pi^e}=0$ and $\sigma_{\hat{u},r}=0$.

[2]For a review of this literature, see Anthony Santomero and John Seater.

II. Principles of Econometric Testing

In this section I present a new econometric test and prove its validity under the neutrality hypothesis. Before doing so, I review the test proposed in Fama (1975). While there are numerous studies of the Phillips curve and the Fisher effect under assumptions of rational expectations,[3] I concentrate on Fama's test since it provides the intellectual genesis for this paper; understanding Fama's test is a prerequisite to understanding the test proposed below.

Fama examined the Fisher effect and rational expectations part of the neutrality hypothesis under the assumption that the real interest rate is constant. His basic test regressed the inflation rate on the nominal interest rate and a constant. This reversal of the usual regression eliminated the errors-in-variables problem associated with using inflation as a proxy for anticipated inflation. The error term in the regression is the unanticipated component of inflation. Since this is uncorrelated with the nominal interest rate, under the null hypothesis, ordinary least squares is appropriate.

In order to set the scene, I have reestimated Fama's basic test using my data set. The results are almost identical to those reported by Fama and would appear to confirm neutrality.

$$(3) \qquad \pi=-\underset{(.358)}{.847}+\underset{(.10)}{.98}\,R$$

$$R^2=.29;\ SER=2.35;\ D\text{-}W=1.76;$$

(monthly data 1/53 to 7/71).

If the real interest rate varies over time, Fama's test is invalid. By design, it does not take advantage of information from the Phillips curve. However his results do appear to provide strong evidence in favor of the neoclassical view. The ingenuity of the test

[3]See notably Bennett McCallum and Thomas Sargent (1976a). For a discussion of some of the problems encountered in a number of studies see Maurice Levi and John Makin (1978; 1979). For further discussion of Fama's test, see John Carlson, Douglas Joines, Charles Nelson and G. William Schwert, and the rejoinder by Fama (1977).

ies in using the stochastic assumptions of he null hypothesis to form a regression vithout using a proxy for anticipated inflaion.

Anticipated inflation cannot be directly observed. This presents a major obstacle to estimation of the Phillips curve and confirmation of the Fisher effect. In the past, various sorts of distributed lags have been used to proxy for anticipated inflation. Such a procedure goes clearly against the spirit of the neutrality hypotheses. However, precisely because both the Phillips curve and the Fisher effect rely on anticipated inflation, the stochastic implications of the neutrality hypothesis can be used, in effect, to decompose nflation into its anticipated and unanticpated components. This decomposition is used to formulate a straightforward regression test that is shown below to be statistically valid if the neutrality hypothesis is true. Such a test allows for the potential refutation of the neutrality hypothesis. In addition, if he neutrality hypothesis is accepted, the test procedure yields a consistent estimate of the Phillips curve tradeoff between unemployment and unanticipated inflation.

By substituting the Phillips curve (2) into he Fisher equation (1) the anticipated inflation term is eliminated. The resulting equation is

$$R = r - \beta\hat{u} + \pi. \tag{4}$$

The real interest rate is not observable unless an identifying assumption is imposed, similar to Fama's assumption that the real rate is constant. Fortunately, knowledge of the real rate is unnecessary. It turns out that the proper econometric test is an ordinary least squares regression of the nominal interest rate on $\hat{u}$ and the inflation rate (and a constant). Under the null hypothesis, the probability limit of the coefficient on inflation is unity and the probability limit of the coefficient $\hat{u}$ is $-\beta$.

Consider the ordinary least squares regression of R on $\hat{u}$ and π, yielding coefficients $\hat{\beta}$ and $\hat{\gamma}$. (Without loss of generality, consider the variables in deviations from sample means and eliminate the constant from the regression.) In the probability limit the various product moments will achieve their asymptotic covariances. The probability limits are given immediately below.

$$\begin{aligned} (5)\quad plim\,\hat{\beta} = \big[& -\beta\sigma_{\hat{u}}^2\sigma_{\pi^e}^2 + \sigma_{\pi^e}^2\sigma_{r,\hat{u}} \\ & + \beta\sigma_{\hat{u},\pi^e}(\sigma_{r,\hat{u}} + \sigma_{\hat{u},\pi^e}) \\ & - \sigma_{r,\pi^e}(\sigma_{\hat{u},\pi^e} + \beta\sigma_u^2)\big] \\ & \big[\sigma_{\hat{u}}^2\sigma_{\pi^e}^2 - (\sigma_{\hat{u},\pi^e})^2\big] \end{aligned}$$

$$(6)\quad plim\,\hat{\gamma} = \frac{\sigma_{\hat{u}}^2\sigma_{\pi^e}^2 - (\sigma_{\hat{u},\pi^e})^2 + \sigma_{\hat{u}}^2\sigma_{r,\pi^e} - \sigma_{r,\hat{u}}\sigma_{\hat{u},\pi^e}}{\sigma_{\hat{u}}^2\sigma_{\pi^e}^2 - (\sigma_{\hat{u},\pi^e})^2}$$

If $\sigma_{\hat{u},\pi^e}=0, \sigma_{r,\pi^e}=0, \sigma_{r,\hat{u}}=0$, then $plim\,\hat{\gamma}=1$ and $plim\,\hat{\beta}=-\beta$.

Therefore $\hat{\gamma}=1$ is an appropriate test[4] of the null hypothesis and $-\hat{\beta}$ is a consistent estimate of the slope of the Phillips curve, conditional on the null hypothesis.[5]

It is perhaps surprising that ordinary least squares provides a valid test. The regression of R on π alone leads to a biased test. Indeed, the insight of Fama's test is that the bias can be avoided by reversing the regression. A regression of R on $\hat{u}$ alone should lead (asymptotically) to a zero coefficient, since under neutrality $\hat{u}$ and R are uncorrelated. While the algebra above provides a formal proof that the regression of R on both $\hat{u}$ and π produces a valid test, two heuristic explanations may lead to greater intuition.

One way to think about the regression procedure is the following. The nominal interest rate contains only anticipated components of inflation. The inflation rate contains both anticipated and unanticipated components and deviations from the natural rate reflect only unanticipated movements of in-

[4]Unlike the original Fama specification, here serial correlation is not inconsistent with rationality, as the expected real interest rate may be serially correlated. Therefore, the consistent estimation of standard errors may require serial correlation correction.

[5]Notice that the test on $\hat{\gamma}$ has zero power against the alternative hypothesis, $\sigma_{r,\hat{u}}=0, \sigma_{r,\pi^e}=0, \sigma_{\hat{u},\pi^e}\neq 0$. In this special case, $\hat{\beta}$ remains a consistent estimator of $-\beta$.

flation. Under rational expectations the anticipated and unanticipated components are orthogonal. The regression projects anticipated inflation in the nominal interest rate onto π. The coefficient on $\hat{u}$ is forced to $-\beta$ in order to "undo" the projection of the unanticipated component in π.

As a second heuristic, consider the properties of the error terms under the null hypothesis. Fama's residuals arose from errors in anticipating inflation. Under rational expectations, these are uncorrelated with π^e. In my regression, residuals arise from variation in the real rate of interest. Under neutrality, these are uncorrelated with both $\hat{u}$ and π. Consideration of the error terms shows that my test and Fama's are similar in that they provide valid estimators only under their respective null hypotheses. If Fama had rejected the hypothesis that his coefficient on R equaled one, then his constant term would not have been a consistent estimate of the real interest rate. If I reject the coefficient of the inflation rate equaling one, then $\hat{\beta}$ is not a consistent estimate of the slope of the Phillips curve.

The test proposed here is a strict superset of Fama's test. In particular, it eliminates the very restrictive assumption of a constant real interest rate. The test uses evidence from both the Phillips curve and the Fisher equation. This has the advantage of extending the testable range of the neutrality hypothesis beyond the hypothesis considered by Fama. Pragmatically, however, consideration of the Phillips curve is not an unmixed blessing. The test here may be quite sensitive to measurement and specification error of the Phillips curve.[6] These cause practical difficulties which are not encountered using Fama's test.

III. Implementing the Test of Neutrality

Testing neutrality and estimating the slop of the Phillips curve can be done in straightforward manner if the natural rate o unemployment is known. I use two classes o estimates of the natural rate. First, I apply statistical filter to monthly unemploymen rates for prime-age male workers. The im plied estimates of $\hat{u}$ are used in regression directly comparable to Fama's work. Second I use several quarterly estimates of the natu ral rate and potential output developed b Jeffrey Perloff and Michael Wachter Monthly estimates are discussed first.

I have chosen interest rate and inflatio data matching Fama's as nearly as possible so that differing results are known to aris out of the test rather than the sample.[7] I us the unemployment rate for prime-age male in order to minimize the effects of demo graphic change. All data is quoted as annua percentage points. The sample consists of th 223 monthly observations from January 195 through July 1971.

As a first statistical model, suppose tha the natural rate is constant, but unknown Let $\hat{u}^*$ stand for the estimate of the natura rate, $\hat{\alpha}$ for the estimate of the unconditiona mean of the real interest rate, $\hat{\beta}$ for th estimate of the slope of the Phillips curve ($\hat{\beta}$ ought to be negative), and use the t-statistic on the hypothesis $\hat{\gamma}=1$ to test neutrality This gives us equations (7a) and (7b)

$$R=\hat{\alpha}+\hat{\beta}\,(\hat{u}^*-u)+\hat{\gamma}\pi+e \tag{7a}$$

$$u=\hat{u}^*-\hat{u} \tag{7b}$$

[6]The execution of the tests assumes a one-sector world. The principles of econometric testing extend directly to the more general case in which unanticipated inflation is due to shocks in any of several markets. If $\hat{\varepsilon}$ represents deviations from equilibrium in, say, the energy markets, then the full expression for the "Phillips curve" ought to be $\pi=\pi^e+\beta\hat{u}+\delta\hat{\varepsilon}$. If covariance conditions for $\hat{\varepsilon}$ analogous to those stated above for $\hat{u}$ hold, then an ordinary least squares regression of R on $\hat{u}$, $\hat{\varepsilon}$, and π produces consistent results. Of course, if the world cannot be described by a one-sector model, then the reported regressions are misspecified due to an omitted variable. Nor would the problem be resolved if $\hat{u}$ and $\hat{\varepsilon}$ happened to be uncorrelated. Indeed, as either a little tedious algebra or a moment's thought will show, the probability limit of $\hat{\gamma}$ goes to one under the null hypothesis only if $\hat{u}$ and $\hat{\varepsilon}$ are perfectly correlated. In such a case $-\hat{\beta}$ would be a consistent estimator of $\beta+\delta$.

[7]Estimation in the paper uses monthly data from 1/53 to 7/71, the same sample period as in Fama (1975). The consumer price index is used to measure changes in purchasing power. The unemployment rate for male workers between ages 25 to 54 is used to eliminate the changes in the natural rate due to the sweeping changes in labor force composition which have occurred in the latter part of the postwar period. The interest rate data used is for Treasury bills, quoted on a discount basis, developed in John Bildersee.

TABLE 1A—ORDINARY LEAST SQUARES BASED TESTS

Equation	$\hat{\alpha}$	$\hat{\beta}$	$\hat{\gamma}$	*SER*	R^2	*D-W*
(7a)	2.73	0.683	0.1897			
	(0.108)	(0.065)	(0.0275)	1.06	.34	.43
(8a)	2.48	0.719	0.298			
	(0.11)	(0.367)	(0.031)	1.28	.33	.62
(8a′)	4.22	−0.206	0.0097			
	(0.80)	(0.045)	(0.0079)	.36	.95	2.33
(7Q)	2.92	0.569	0.2435			
	(0.21)	(0.099)	(0.0751)	.89	.64	.69
(8Q)	0.209	2.604	0.2279			
	(0.412)	(0.444)	(0.0757)	.88	.64	.67
(9Q)	2.54	0.228	0.3215			
	(0.19)	(0.045)	(0.0715)	.93	.61	.80

TABLE 1B—FILTER RULES

Equation		Coefficient Estimates[a]							*SER*	R^2	*D-W*
(7b)	u^*	3.27									
		(0.079)							1.18	.00	.04
(8b)	ρ_0	.1597		1.032		0.201		−0.281			
		(0.0461)	ρ_1	(0.064)	ρ_2	(0.094)	ρ_3	(0.064)	.23	.96	1.90
(9b)	ρ_0	.113		1.054		0.172		−0.259			
		(0.046)	ρ_1	(0.063)	ρ_2	(0.092)	ρ_3	(0.063)	.23	.96	1.95

[a]Standard errors are shown in parentheses.

Equations (7a) and (7b) can be estimated ither by full-information maximum likeli-ood or by substituting (7b) into (7a) and sing ordinary least squares. As there are no veridentifying cross-equation restrictions, he two methods are equivalent. *FIML* stimates are presented in the first lines of ables 1A and 1B. $\hat{\gamma}$ is approximately 30 tandard errors away from one and $\hat{\beta}$ is 10 tandard errors on the wrong side of zero. Vhile this might indicate a rejection of neu-rality, it seems more sensible to reject the iew that the natural rate is constant; this vould also account for the 0.04 Durbin-Vatson statistic reported for equation (7b).

As a second statistical model I apply a ilter rule to the unemployment rate. Under he null hypothesis, deviations of unemploy-nent from the natural rate ought to be white ioise. Following Sargent (1973) and many thers, I estimate a filter which splits unem-loyment into a serially correlated series for he natural rate and a set of white noise innovations.[8] Several simple filters were tried, all yielding approximately the same results when used in estimation. A third order auto-regressive series is shown in equations (8a) and (8b) and in Table 1A.

$$\text{(8a)}\quad R=\hat{\alpha}+\hat{\beta}\,(\hat{\rho}_0+\hat{\rho}_1u_{-1}+\hat{\rho}_2u_{-2}+\hat{\rho}_3u_{-3}-u)+\hat{\gamma}\pi+e;$$

[8]Even though this is a very popular technique—being a somewhat simpler version of that used by Robert Barro in a series of articles on "unanticipated money" (1977, 1978), for example—one probably ought to be less than sanguine about its use. While statistical properties can be used to reject the hypothesis that a particular series represents unanticipated deviations from the natural rate, no purely statistical test can be applied to the series which allegedly represents the natural rate itself. Of course, this filter is valid only under the null hypothesis. If rationality is rejected we cannot make use of the estimates of $\hat{u}$ for other purposes. The illustrative tests are conditional on the assumption that the estimated model adequately captures the time series properties of the natural rate. For further discussion, see Sargent (1976) and J. D. Germany and S. Srivasta.

(8b) $u=\hat{\rho}_0+\hat{\rho}_1 u_{-1}+\hat{\rho}_2 u_{-2}+\hat{\rho}_3 u_{-3}-\hat{u}.$

As a further check on the filter rule, I estimated (8a) and (8b) both separately and jointly and tested equality of the $\hat{\rho}$'s in the two equations. The test statistic, which is distributed (asymptotically) $F(3,213)$, equaled 0.97, so the filter rule cannot be rejected at any of the usual levels of statistical significance.

The *FIML* estimates of (8a) and (8b), imposing the identifying restriction that $\hat{u}$ and e are independent are reported in Tables 1A and 1B. $\hat{\beta}$ is two standard errors on the wrong side of zero. The test of rationality, $\hat{\gamma}=1$, fails by about 22 standard errors.

The Durbin-Watson statistic indicates serious autocorrelation in equation (8a). Neutrality places no restrictions on the time-series behavior of the real rate, so it is not surprising that the error terms in (8a) are serially correlated. Ordinary least squares estimation in the presence of serial correlation produces consistent estimates, however, the estimates will be inefficient and reported standard errors will be incorrect. Thus, for reasons of statistical accuracy, it is desirable to use a generalized least squares procedure to eliminate as much of the serial correlation as possible.[9] I corrected equation (8a) for first-order serial correlation and reestimated. The results, reported as (8a′) and (8b′), in Table 1, are surprisingly different from the preceding estimate. The slope of the Phillips curve shows that a one-point reduction in the unemployment rate is associated with a twenty basis point increase in inflation. This slope coefficient is 2 standard errors on the correct side of zero. However, the estimate of γ is now 126 standard errors below one.

Perloff and Wachter have prepared estimates of the natural rate of unemployment and potential output measured quarterly. Their estimates adjust for demographic changes in the labor force and then further filter for expected changes in inflation. (Their filters use only lagged variables, so their na ural rate estimates are legitimate for the pu pose at hand.) Beyond the advantage of carefully constructed estimate of the natur rate, there are some inherent advantages c quarterly over monthly data. In particula the survey dates of the monthly *CPI* may nc be well synchronized with bond holding per ods. Such noise problems are less importan for quarterly data. The following estimation use the Perloff-Wachter series U_2^* (the natu ral rate of unemployment) and *QPOT* (potential output) from 1953:I throug 1971:II. The nominal interest rate data is fo three-month Treasury bills. The timing o interest and inflation rate data is matche with the quarterly unemployment figures.

The basic regression is reported in lin (7Q) of Table 1A. $\hat{\gamma}$, .24, is 10 standard error below 1. Since a high degree of serial correla tion is indicated, I also estimated (7Q) co recting for serial correlation. The resul (omitted from the table to conserve space pushed $\hat{\gamma}$ slightly negative, to 25 standar errors below one.

It is generally acknowledged that th Phillips curve really does curve. In (8Q) used the ratio of the natural rate to th observed unemployment rate as the measur of deviations from full employment. (Not that this means that the estimate of the mea real interest rate is $\hat{\alpha}+\hat{\beta}$, since at full em ployment u/u^* equals one.) The point esti mate of $\hat{\gamma}$, 0.23, is again 10 standard error below one. Correction for serial correlatio had the same results as in the previous case

Perloff and Wachter provide a series o potential *GNP* that is an analogue to thei unemployment series. Deviations of outpu from potential output may well be a bette measure of excess demand than are the un employment measures used above. In (9Q) I use the percentage deviation of output from potential output, $100^*(Y-Y_P)/Y_P$, to mea sure excess demand. The estimated Phillip curve again slopes significantly the wrong way. $\hat{\gamma}$ is 9.5 standard errors below one Serial correlation correction again reinforces the results.

The inescapable conclusion of these il lustrative tests is that simple statements o neoclassical neutrality are contradicted by the empirical evidence.

[9] *GLS* correction, including the Cochrane-Orcutt transformation used here, makes a linear transformation of the variables. The independence of the untransformed errors with the right-hand side variables is preserved by such a transformation.

IV. Long-Term Contracts and Rational Expectations

Stanley Fischer (1977a, b) modifies neo-lassical rational expectations results by re-ognition of long-term nominal contracts. ;ven if expectations are fully rational, ex-ected inflation has real effects when expec-ations are formed after contracts are signed. n particular, deviations of unemployment rom the natural rate persist during the life f the longest outstanding contract. Accord-ng to long-term contracting theory, the bserved serial correlation of the unemploy-nent rate arises from serial correlation in $\hat{u}$, /here the more purely neoclassical theory xplored in the previous sections requires erial correlation in the unemployment rate o arise solely out of serial correlation in the atural rate. In this section of the paper, I xtend the econometric principles suggested bove into a test of one variant of long-term ontracting theory. Specifically, I maintain he hypotheses of rational expectations and he independence of the real interest rate rom anticipated inflation, but allow for per-istent deviations of unemployment from the atural rate. By combining information from nterest rates of different maturities the per-istence pattern of $\hat{u}$ can be replicated and he long-term contracting hypothesis can be ested.

I develop the theory in terms of one- and wo-period contracts and then state the xtension to the k period case. Suppose a raction θ of all contracts start in the current eriod and that $(1-\theta)$ carry over from the revious period. Letting E_tP_{t+1} be the expec-ation of the logarithm of the general price evel at time $t+1$, conditional on informa-ion available at time t, and letting $\hat{u}_t$ be the leviation from the natural rate of unemploy-nent at the end of period t, we have a nodified Phillips curve.

$$9)\quad \hat{u}_t=\{\theta[P_{t+1}-E_tP_{t+1}] +(1-\theta)[P_{t+1}-E_{t-1}P_{t+1}]\}/\beta.$$

Deviations from the natural rate depend n errors in the one-period inflation forecast nade at time t and the two-period inflation orecast made at time $t-1$. The one-period time t forecast is also built into the one-period time t nominal interest rate and the time $t-1$ two-period forecast is in the time $t-1$ two-period nominal interest rate.

At time, t, r_t^i and R_t^i are the i period expected real rate and nominal rate, respectively. The nominal rates matching contracts which expire in the current period are shown in (10) and (11):

$$(10)\qquad R_t^1=r_t^1+E_tP_{t+1}-P_t;$$

$$(11)\quad 2R_{t-1}^2=2r_{t-1}^2+E_{t-1}P_{t+1}-P_{t-1}.$$

Equation (12) shows the substitution of (9) into a weighted average of (10) and (11):

$$(12)\quad \theta R_t^1+(1-\theta)2R_{t-1}^2=\{\theta r_t^1+(1-\theta)2r_{t-1}^2\} -\beta\hat{u}_t+\theta(P_{t+1}-P_t)+(1-\theta)(P_{t+1}-P_{t-1}).$$

In (13), (12) is rearranged in a form suitable for estimation.

$$(13)\quad R_t^1=\left\{r_t^1+\frac{1-\theta}{\theta}2r_{t-1}^2\right\} -\frac{\beta}{\theta}\hat{u}_t+(P_{t+1}-P_t) -\frac{1-\theta}{\theta}\{2R_{t-1}^2-(P_{t+1}-P_{t-1})\}.$$

Just as in the previous section, the coefficient on the inflation rate equals one under the null hypothesis. The contract weights can be retrieved from the coefficient on the last term in (13). Notice that if θ equals one, equation (13) reduces to the model of the previous section.

The generalization of (13) to the k period contract case is shown in (14).

$$(14)\quad R_t^1=\left\{\sum_{j=1}^{k}\frac{\theta_j}{\theta_1}\left(jr_{t-j+1}^j\right)\right\} -\frac{\beta}{\theta_1}\hat{u}_t+(P_{t+1}-P_t) -\left\{\sum_{j=2}^{k}\frac{\theta_j}{\theta_1}\left(jR_{t-j+1}^j-(P_{t+1}-P_{t-j+1})\right)\right\}$$

TABLE 2—INSTRUMENTAL VARIABLE ESTIMATES FOR LONG-TERM CONTRACTS

Periods	$-\beta$	γ	θ_1	Dates	*SER*	*D-W*
1–3	1.0	−0.0013	0.838			
	(0.15)	(0.0667)	(0.041)	1/53-7/71	1.52	0.28
1–6	0.481	0.0010	0.933			
	(0.67)	(0.0343)	(0.024)	6/59-7/71	0.558	0.71
1–9	−1.25	0.0311	0.956			
	(1.41)	(0.1246)	(0.203)	7/64-7/71	1.342	0.61
1–12	−1.52	−0.038	0.898			
	(2.86)	(0.226)	(0.148)	7/64-7/71	2.37	0.97
1–3[a]	−1.45	0.0088	0.745			
	(0.91)	(0.0960)	(0.056)	1/53-7/71	2.21	0.34
1–12[a]	3.04	0.0019	0.998			
	(5.34)	(0.2399)	(0.192)	7/64-7/71	2.55	0.94

[a]Using (8b).

where $$\sum_{j=1}^{k} \theta_j = 1.$$

The last term, the long-term *ex post* real interest rate, is highly correlated with the unobserved long-term expected real interest rate. Ordinary least squares is inconsistent even under the null hypothesis.

For consistent estimation, it is necessary to purge the last term of correlation with the expected real rate while retaining correlation with unanticipated inflation. The *ex post* real rate contains an expected real rate component and an unanticipated inflation component. The inflation rate is uncorrelated with the former under the null hypothesis and is of necessity correlated with the latter. The j period inflation rate, $P_{t+1}-P_{t-j+1}$, is therefore a perfect instrument for the j period *ex post* real rate. Equation (14) can be consistently estimated, under the null hypothesis, using as instruments $k-1$ multiperiod inflation rates, a constant, $\hat{u}$, and π_t.

The first four lines of Table 2 present results for 1–3, 1–6, 1–9, and 1–12 period contracts, based again on a constant natural rate.[10] The test of the null hypothesis, $\hat{\gamma}=1$, can be rejected by t-statistics of 15, 29, 7.7, and 4.6, respectively. In the last two lines of Table 2, I have reestimated using (8b) to form $\hat{u}$. The null hypothesis is still decisively rejected. The empirical evidence lends n support to this particular variant of long-ter contracting theory.

[10]Due to data limitations the regressions for longer-term contracts cover considerably shorter periods.

V. Conclusion

This paper has two parts. First, econome ric tests are developed in order to test som of the classical neutrality propositions. Se ond, these tests are illustrated on simpl formulations of the neutrality proposition The tests repeatedly reject the null hypoth sis.

In light of the strong rejection, it seem valuable to review possible extensions to th way the testing principles are implemente First, the identification of real market shock other than those correlated with unemplo ment would eliminate a possible source o asymptotic bias. Second, correction for ta effects might be very important. Howeve the most straightforward corrections sugge we ought to have observed $\hat{\gamma}$ greater tha not less than, one. Third, correction for ris aversion should be considered since there i at least casual evidence that periods of hig expected inflation are associated with su stantial inflation uncertainty. Fourth, th coverage of the long-term contract tests oug to be extended to a longer period.

These caveats notwithstanding, the tes are done on much the same terms as prev ous tests that have tended to support th neutrality propositions. The strong rejection

ıf the null hypothesis cast serious doubt on he simpler representations of the neoclassi-al school of macroeconomic thought.

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The Simple Analytics of Neo-Ricardian Growth and Distribution

By WILLIAM A. DARITY, JR.*

A subject of continued dispute has been the essential difference between neoclassical and Keynesian theories of growth and distribution. In a recent essay, Hans Brems argues that the key dissimilarities are technological and ontological. Brems contends that the neoclassical model is characterized by an aggregate production function that permits substitution between factors of production while the Keynesian model is characterized by an aggregate production function of the fixed coefficients variety.[1] Brems also contends, discussing the version of the Keynesian model he attributes to Joan Robinson, that entrepreneurial behavior violates conventional optimizing motives. He writes: "Her profit share as well as her mark-up factor are determined by letting nonprofit-maximizing and otherwise nonrational entrepreneurs fix an arbitrary growth rate of capital stock" (p. 165).

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[1]It should be noted that Nicholas Kaldor (1966, p. 310) has suggested that the relevant technology for growth theory is one with increasing returns. Such a technological imputation precludes the competitive market conditions that make neoclassical factor pricing a logical possibility. Therefore, this richer view of technology is ignored here. The neoclassical "state of affairs" conception of competition also can be called into question. The neoclassical view of competition leads to a ranking of market structures along a continuum from perfect competition to pure monopoly. An alternative notion of competition, more closely in step with Ricardo's conception, would focus solely on capital's ability to bridge profit rate differentials (see, for example, James Clifton). This line of argument will not be pursued here either, especially since the present analysis proceeds in a one-sector world.

I propose an alternative view. It will not be necessary to make contrasting assumptions about technology nor the motives of participants in the economy. Throughout this paper an aggregate neoclassical production function will be used in both settings. Entrepreneurs will satisfy the behavioral dictates of being "profit maximizers" and "rational" in the customary senses.

What will separate neoclassical and Keynesian approaches is the environment with which these optimizing entrepreneurs are confronted on the key dimension of uncertainty. The neoclassical world is one of perfect foresight. The Keynesian world is one of *subjective* uncertainty. The role of subjective uncertainty, of the Keynes-Shackle variety, is emphasized by Sidney Weintraub in his critique of Brem's typology: "... Brems tells us nothing about 'rational' behavior in an uncertain world, especially when different people glimpse the future differently, or about how one goes about maximizing 'profits' when the appropriate demand and cost functions, envisaged in a time context, are subjective and uncertain" (1979, p. 139).

The neoclassical approach to "uncertainty" reveals the substance of the difference. "Rational expectations," for example, is *still* perfect foresight about the *systematic* determinants of a variable about which expectations are being formed. Thus neoclassical economics really ends up doing "risk" analysis, rather than uncertainty analysis, in Frank Knight's sense:

> The essential fact is that "risk" means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomenon depending on which of the two is really present and operating.... It will appear that a *measurable*

> uncertainty, or "risk" proper... is so far different from an *unmeasurable* one that it is not in effect an uncertainty at all. We shall accordingly restrict the term "uncertainty" to cases of the non-quantitative type. [pp. 19–20]

t is Knightian risk that pervades a neoclassi-al world, while it is Knightian uncertainty hat pervades the Keynesian world.

Corresponding to the conflicting treat-nents of foresight are conflicting theories of he rate of profit. In the neoclassical theory, he rate of profit is determined by the pro-luctivity of capital. In the Keynesian model, he rate of profit becomes a monetary phe-nomenon.[2] The personality of long-run growth and distribution is sensitive to the nderlying theory of the profit rate. Each heory implies a unique tale of short-run lynamics for a growing closed economy. This n turn leads to a unique characterization of he long-run consequences of growth. The hort run will be defined as the period in vhich the capital stock is fixed or given.

In addition to the common characteriza-ion of technology and entrepreneurial mo-ives, both approaches will share some form of the Cambridge–neo-Ricardian saving equation.[3] Following Alpha Chiang, the most general form of the Cambridge saving equation can be specified as follows:

$$(1) \qquad S=s_w(Y-rK)+s_w(1-s_p)rK_w + s_c(1-s_p)rK_c+s_prK$$

where S = aggregate saving
Y = real output
r = rate of profit on capital
K = aggregate capital stock
K_w = capital owned by labor
K_c = capital owned by capitalists
s_w = labor's propensity to save
s_c = rentiers' propensity to save
s_p = corporate retention ratio.

Equation (1) reveals that corporations save a fixed proportion, s_p, of real profits (rK) as retained earnings. The remainder of profits is then distributed to the shareholders, who in turn apply their personal saving propensity to the residual. Out of this general population of owners of the capital stock, there can be two hereditary classes—one that receives only profit income and a class that receives some profits and wages. The former is a pure "rentier" class with the fixed saving rate s_c, while the latter are the "workers" with the fixed saving rate s_w.

It must be true that the sum of labor-owned and rentier-owned capital add up to the aggregate capital stock:

$$(2) \qquad K=K_c+K_w.$$

The saving equation developed by Kaldor (1956) now can be interpreted as a special case of (1) that sets $s_c=s_w$, given (2), so that

$$(3) \qquad S=s_wY+(1-s_w)s_prK.$$

If there is a hereditary rentier class—a class that receives only profit income—Kaldor is not concerned. Rentier households are assumed by Kaldor to save the same fixed

[2]Even Piero Sraffa in his now classic attempt to overturn the marginal productivity theory of distribu-ion resorted to a monetary explanation of the profit rate: "The Rate of profits, as a ratio has a significance which is independent of any prices, and can well be 'given' before the prices are fixed. It is accordingly susceptible of being determined from outside the system of production, in particular by the level of the money rates of interest" (p. 33).

[3]Since an aggregate neoclassical production function is used in both contexts, capital is always a homogeneous (nonhuman) factor of production in this essay. This divorces attention from the capital controversy (see Geoffrey Harcourt). Accumulation thus means an increase in the size of this factor of production—the concept of accumulation both neoclassical and Keynesian thought share from their common roots in classical political economy. Plainly this is *not* a Marxist notion of either capital or accumulation. Karl Marx's conceptions of capital and accumulation were fundamental to his deep break with political economy. For Marx, "capital" was a social relationship between the elemental classes under the capitalist mode of production. Accumulation for Marx can be interpreted as the *extension* of this social relationship. Nor is the *homogeneous* factor of production notion of capital genuinely consistent with John Maynard Keynes' views either—at least not the Keynes of *The General Theory* (especially chs. 11 and 16).

proportion of all income received, s_w, as households that receive labor income.

Luigi Pasinetti's saving equation can be interpreted as a special case of (1) that sets $s_p=0$:

$$S=s_wY+(s_c-s_w)rK_c. \tag{4}$$

In the world that Pasinetti depicts, it is solely distribution of ownership rights between the two hereditary classes that is relevant. All saving is done by households—rentier and laboring households.

In the presentation of the neoclassical approach to growth and distribution theory, a pure Kaldor, a pure Pasinetti, and an integrated Kaldor-Pasinetti system all will be considered below. The neoclassical version of the Kaldor system will display steady-state properties akin to the single saving propensity Solow-Swan model. The neoclassical version of the Pasinetti system will display the range of potential long-run outcomes identified by Paul Samuelson and Franco Modigliani. One possible long-run outcome they identified was a case where rentiers and workers own fixed shares of the capital stock —a Pasinetti equilibrium. The other possible long-run outcome they discovered was a case where workers gain ownership of the entire capital stock—what Samuelson and Modigliani called the "Dual equilibrium."

It is in the subsequent analyses that new results emerge:

In the neoclassical version of the *integrated* Kaldor-Pasinetti (K-P) system the Dual equilibrium is eliminated. Although an equilibrium is still possible where wage earners and capitalists eventually own fixed shares of the capital stock, the corresponding secular rate of profit will not take the Pasinetti paradox value.

In the Keynesian model of growth and distribution, three different long-run outcomes are possible. Not only are the Pasinetti and Dual equilibria potential results of growth, but there is a third possibility—a case of perpetual dynamic disequilibrium where the capitalists acquire an ever-increasing share of the capital stock. This will be called an anti-Dual outcome counterposed against the Samuelson-Modigliani Dual equilibrium.

In the Keynesian model it is shown that the long-run profit rate need not converge to the marginal product of capital.

I. Neoclassical Growth and the Cambridge Saving Equation

Let us begin with a standard neoclassical production function where real output (Y) is positively related to inputs of capital (K) and employed labor (N):

$$Y=Y(K,N). \tag{5}$$

Inada conditions (see Edwin Burmeister and A. Rodney Dobell) are assumed to apply so that (5) represents a constant returns to scale production function. This means that (5) can be rewritten in Solow (1956) "intensive" fashion by dividing through both sides by the total available labor force L. This means the production function expresses real output in per capita terms:

$$y=Y(k,n); \tag{6}$$

$$Y_k>0, Y_n>0, Y_{kk}<0, Y_{nn}<0;$$

$$y\equiv(Y/L)\,k\equiv(K/L)\,n\equiv(N/L).$$

The y is real output per head, k is capital per head, and n is the employment rate.

Simultaneously a function is defined for the average product of capital. The derivative of this function with respect to the capital-total labor ratio will be negative. The derivative with respect to the employment rate will be positive. The Inada conditions also imply that the average product of capital always exceeds the marginal product of capital except where the capital-total labor ratio is zero or infinity:

$$Y/K=a(k,n); \tag{7}$$

$$a_k<0,\ a_n>0,\ a(k,n)>Y_k \text{ if } 0<k<\infty.$$

In a neoclassical context the operation of Say's Law (see Joan Robinson, 1966, p. 308) means that all saving is invested, that is, all saving automatically becomes additions to the capital stock. Aggregate capital accumu-

lation is determined directly by aggregate saving.

The complete system can be depicted with three equations of motion—an equation for aggregate capital accumulation and an equation for each income class' accumulation of capital. With dotted variables representing time derivatives, these are

$$(8)\quad \dot{K}=s_w(Y-rK)+s_w(1-s_p)rK_w+s_c(1-s_p)rK_c+s_prK;$$

$$(9)\quad \dot{K}_w=s_w(Y-rK)+s_w(1-s_p)rK_w;$$

$$(10)\quad \dot{K}_c=s_c(1-s_p)rK_c+s_prK.$$

Next assert that there is an exogenously given growth rate of the available labor force—or population. This rate is the Harrodian "natural rate" g:

$$(11)\quad \dot{L}/L=g.$$

Recall that k is capital per head. Define two new variables, k_c and k_w, as the capitalists' and workers' shares of the capital stock, respectively. Note also that the following relationships flow directly from condition (2) above:

$$(12)\quad 1=k_c+k_w;$$

$$(13)\quad \dot{k}_c=-\dot{k}_w.$$

With these notational additions the three equations of motion, (8), (9), and (10), can be rewritten in per capita and income shares form as follows:

$$(14)\quad \frac{\dot{k}}{k}=\frac{\dot{K}}{K}-\frac{\dot{L}}{L}=s_w[a(k,n)-r]+(1-s_p)[s_w+(s_c-s_w)k_c]r+s_pr-g;$$

$$(15)\quad \frac{\dot{k}_w}{k_w}=\frac{\dot{K}_W}{K_W}-\frac{\dot{K}}{K}=\frac{s_w[a(k,n)-r]k_c}{(1-k_c)}-(s_c-s_w)(1-s_p)rk_c-s_pr;$$

$$(16)\quad \frac{\dot{k}_c}{k_c}=s_c(1-s_p)r+\frac{(1-k_c)}{k_c}s_pr-s_w[a(k,n)-r]-(1-s_p)\times[s_w+(s_c-s_w)k_c]r.$$

Inspection of the model in the form of equations (14), (15), and (16) reveals three equations in the four unknowns, k, k_c, n, and r. Neoclassical growth theorists frequently assume continuous full employment. This sets $n=1$ permanently, which eliminates one unknown (as well as an empirically relevant feature of modern economies).

Due to condition (13) one of the latter two equations is redundant and can be dropped. Dropping the middle equation, (15), collapses the system to two equations of motion:

$$(17)\quad \dot{k}=\{s_w[a(k,1)-r]+(1-s_p)\times[s_w+(s_c-s_w)k_c]r+s_pr-g\}k;$$

$$(18)\quad \dot{k}_c=\{s_c(1-s_p)r-s_pr-s_w[a(k,1)-r]-(1-s_p)[s_w+(s_c-s_w)k_c]r\}k_c+s_pr.$$

The system is still underdetermined because there are two equations but three unknowns—k, k_c, and r. Short-run neoclassical distribution theory eliminates another unknown by setting the profit rate equal to the marginal product of capital. This, by implication, also sets the real wage equal to the marginal product of labor. The perfectly competitive market structure that generates short-run marginal product factor pricing provides a justification for the neoclassical assumption of continuous full employment.

By setting the rate of profit permanently equal to the marginal product of capital and by assuming continuous full employment, the neoclassical version of the Kaldor-Pasinetti system becomes determinate. To depict their respective dynamic equilibria, both Kaldor and Pasinetti assumed full employment would obtain in both the short and long run. But they did not assume that

marginal product factor pricing held in a short period. In fact, Kaldor (1956) undertook his investigation with the intent of providing an escape from marginal product distribution theory.

The seeming inconsistency between the full-employment assumption and the absence of marginal product factor pricing left the door open for Samuelson and Modigliani (1966) to incorporate the Pasinetti saving equation into a thoroughly neoclassical model of economic growth. Hence assuming $r=Y_k$ is the essence of their analytical strategy. By following suit here their basic results can be reproduced.

Since the Cambridge saving equation in (8) is sufficiently general to encompass K-P's analyses, the system described by equations (17) and (18) can provide answers about *both* the long-run distribution of functional shares and the long-run distribution of ownership rights to the capital stock between labor and capital. Moreover, by first setting $s_c=s_w$ and then by setting $s_p=0$, it is also possible to examine the dynamics of the "pure" K-P systems once the model is determinate.

After neoclassical short-run distribution theory and continuous full employment are incorporated into the two equation system, (17) and (18), the model is completely determined. The only remaining unknowns become k and k_c in a system of two differential equations:

$$(19)\quad \dot{k}=\{s_w[a(k,1)-Y_k]+(1-s_p)\times[s_w+(s_c-s_w)k_c]Y_k+s_pY_k-g\}k;$$

$$(20)\quad \dot{k}_c=\{s_c(1-s_p)Y_k-s_pY_k-s_w[a(k,n)-Y_k]-(1-s_p)[s_w+(s_c-s_w)k_c]Y_k\}k_c+s_pY_k.$$

A. "*Pure*" *Kaldor*

First, consider the pure Kaldor system in a neoclassical context. Since it is a system where different saving propensities are associated with different types of income, rather than the saving decisions of members of different hereditary classes, there is no need for the second equation of motion. Setting $s_c=s_w$ compresses the aggregate accumulation equation into the form immediately below:

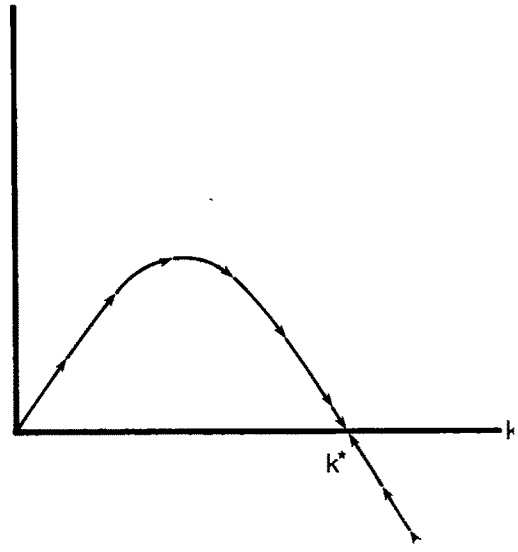

FIGURE 1

$$(21)\quad \dot{k}=\{s_w[a(k,1)-Y_k]+(1-s_p)s_wY_k+s_pY_k-g\}k.$$

This leaves one equation and one unknown, k, the capital intensity.

Dynamic equilibrium for an economy growing in this fashion will require growth to be balanced in the sense that the percentage rate of increase of the capital stock must equal the percentage rate of increase of the labor force. The steady-state condition is $\dot{k}=0$, which can occur under two circumstances: (i) Either the long-run capital intensity vanishes:

$$(22)\quad k=0;$$

or (ii) it will be the positive value $k=k^*$ that solves:

$$(23)\quad (1-s_w)s_pY_k=g-s_wa(k,1).$$

It can be demonstrated easily that the second solution is the only stable one from inspection of the phase diagram associated with equation (21). Global stability of k^* is evident in Figure 1. This phase diagram provides a geometric stability proof which is conceptually no different from the stability proof in the ordinary single saving propensity Solow-Swan neoclassical growth model.

In the diagram to the left of k^* the capital intensity is rising since the capital stock's percentage growth rate exceeds the natural growth rate, while to the right of k^* the capital intensity is falling since the opposite is true. From any initial capital-total labor ratio the steady-state capital intensity k^* is known so that

$$(24) \qquad r=Y_k(k^*)=\frac{g-s_w a(k^*,1)}{(1-s_w)s_p}.$$

When households save nothing ($s_w=0$), it implies under conditions of positive population growth ($g>0$) that the rate of profit must equal the ratio of the natural growth rate to the corporate retention ratio. On the other hand, as the corporate retention ratio approaches zero—yielding a world where only one saving propensity applies to both types of income—the secular profit rate approaches infinity.

The steady-state profit share when the Kaldor saving equation is imbedded in a neoclassical world will be[4]

$$(25) \qquad \frac{g-s_w a(k^*,1)}{(1-s_w)s_p a(k^*,1)};$$

and the wage share will obviously be

$$(26) \qquad 1-\frac{g-s_w a(k^*,1)}{(1-s_w)s_p a(k^*,1)}.$$

B. "*Pure*" *Pasinetti*

To illustrate the dynamic properties of the Samuelson-Modigliani neoclassical version of the pure Pasinetti system necessitates three steps: (a) assume $1>s_c>s_w>0$, rather than setting $s_c=s_w$; (b) assume $s_p=0$; and (c) retrieve the separate accumulation equation for capitalists.[5] The system in (19) and (20) specializes to

$$(27) \qquad \dot{k}=\{s_w a(k,1)+(s_c-s_w)Y_k k_c-g\}k;$$

(28)

$$\dot{k}_c=\{s_c Y_k-s_w a(k,1)-(s_c-s_w)Y_k k_c\}k_c.$$

Phase diagrams also will help reveal this system's behavior through time. A k_c, k phase space is plainly the relevant one.

First determine the shape and slope of the $\dot{k}=0$ locus. Equation (27) implies at the steady state:

$$(29) \qquad (s_c-s_w)Y_k k_c=g-s_w a(k,1);$$

which means in turn that

$$(30) \qquad k_c=\frac{g-s_w a(k,1)}{(s_c-s_w)Y_k}.$$

[4]In the case of a Cobb-Douglas production function, $y=k^\alpha$ and $0<\alpha<1$, the profit and wage share must be α and $(1-\alpha)$, respectively, under marginal product factor pricing. This obviates what is of interest in Kaldor's exercise, the determination of the secular functional distribution of income. However, with such an algebraically specified production function a calculable value of the steady-state capital stock can be derived directly from (23):

$$k^*=[g/(1-s_w)s_p\alpha+s_w]^{1/(\alpha-1)}.$$

For example, if $g=.03$, $s_w=.1$, $s_p=.5$, and $\alpha=.5$, $k^*\simeq .18$.

[5]There is nothing in principle that precludes $s_w<0$—or workers engaging in perpetual dissaving—bartering the future indefinitely to the capitalist class. The economy is then analogous to a huge company store. Kaldor has written: "There is nothing in the model which requires s_w to be positive—the model works just as well when it is negative, with the business sector being a net lender, not a net borrower, to the personal sector" (1966, pp. 313–14). Obviously Kaldor's comment is in reference to his own version of the saving equation, but the observation also applies for Pasinetti's model. It would require intergenerational or interclass financing mechanisms to be introduced into the model. However, treating s_w as negative unduly complicates the dynamic analysis. Therefore s_w will be assumed to be strictly positive, although probably small, throughout the paper.

Consequently the slope of the $\dot{k}=0$ locus is given by

$$(31)\quad \frac{dk_c}{dk}=-\left(\frac{s_wY_k}{(s_c-s_w)Y_k}+\frac{k_cY_{kk}}{Y_k}\right).$$

The expression in (31) indicates that the slope of the $\dot{k}=0$ locus can change sign over the interval of economically meaningful values of the capital-total labor ratio, $(0,\infty)$. To plot the $\dot{k}=0$ locus in the appropriate phase space the expression in (30) is more helpful. The Inada conditions assure that for low values of k, $s_wa(k,1)>g$. Therefore to keep $\dot{k}=0$ at low values of k requires negative values of k_c. When g exceeds $s_wa(k,1)$, positive values of k_c will keep the capital intensity stationary.

Next determine the shape and slope of the $\dot{k}_c=0$ locus. The important discovery that Samuelson and Modigliani made that led them to some provocative criticisms of Pasinetti's system was to notice that there are two branches to this locus. One branch corresponds to all combinations of values of k and k_c that set

$$(32)\quad (1-k_c)s_cY_k=s_w[a(k,1)-Y_kk_c].$$

The second branch corresponds to $k_c=0$. When rentier capitalist households receive no income, the entire horizontal axis in k_c, k phase space is the $\dot{k}_c=0$ locus.

To isolate the qualitative features of the branch of the $\dot{k}_c=0$ locus associated with condition (32) solve directly for k_c as a function of k:

$$(33)\quad k_c=\frac{s_c}{s_c-s_w}-\left(\frac{s_w}{s_c-s_w}\cdot\frac{a(k,1)}{Y_k}\right).$$

The slope of this branch of the branch of the $\dot{k}_c=0$ locus is

$$(34)\quad \frac{dk_c}{dk}=-\frac{s_w}{s_c-s_w}\,\frac{Y_ka_k-Y_{kk}a(k,1)}{(Y_k)^2},$$

which is ambiguous in sign a priori. The sign and therefore the shape of the locus depends upon the elasticity of substitution between capital and labor. In the diagrams that appear below, three cases are examined that exhaust the possibilities for this system, depending upon the shape of this branch of the $\dot{k}_c=0$ locus.[6]

One final proviso before examining the phase diagrams: since k_c is the (rentier) capitalists' share of the total capital stock, it must be constrained to lie on the interval $[0,1]$. However as k_c approaches unity, the values of the capital intensity that will maintain $\dot{k}_c=0$ along the branch of the locus associated with condition (32) can become explosively large. When $k_c=1$, condition (32) implies that the average product of capital equals the marginal product of capital, which can only occur when $k=0$ or $k=\infty$ under the Inada conditions. The former condition is economically uninteresting, but the latter condition implies that in regions where k_c approaches one, or k becomes large, this second branch of the $\dot{k}_c=0$ locus must lie to the right of the $\dot{k}=0$ locus in k_c, k phase space. *This characteristic of the locus is due to the neoclassical closing that sets $r=Y_k$.*

The central cases appear in Figures 2, 3, and 4. The arrows reveal the direction of motion for the time paths of capital intensity and the rentier class' share of the capital stock from any initial point in the relevant regions of the diagrams.

In Figure 2, two distinct equilibria exist—one which is appropriately called the Pasinetti steady state (a P point) and the one which Samuelson and Modigliani called the Dual equilibrium (a D point). The phase diagram shows that the P point is locally stable—so when both equilibria exist the system will tend towards a long run where both workers and rentier capitalists eventually hold fixed positive proportions of the capital stock. At a P point the steady-state profit rate takes the Pasinetti paradox value. In a neoclassical world the capital intensity adapts to make the marginal product of capital equal the ratio of the natural growth rate to the rentier capitalists' saving rate. Therefore the follow-

[6]With a constant elasticity of substitution production function it can be shown that if the elasticity of substitution is less than one, this branch of the $\dot{k}_c=0$ locus can be negatively sloped. When the elasticity of substitution exceeds one, it can be positively sloped.

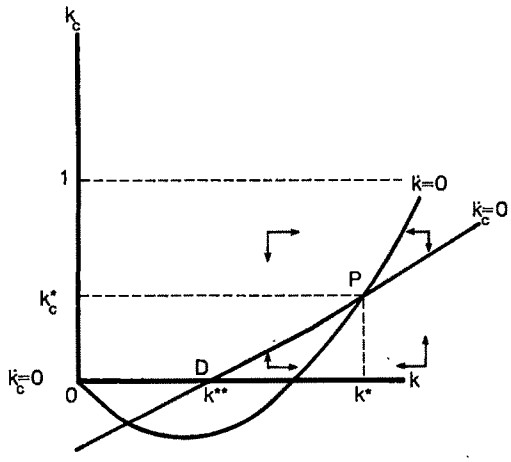

FIGURE 2

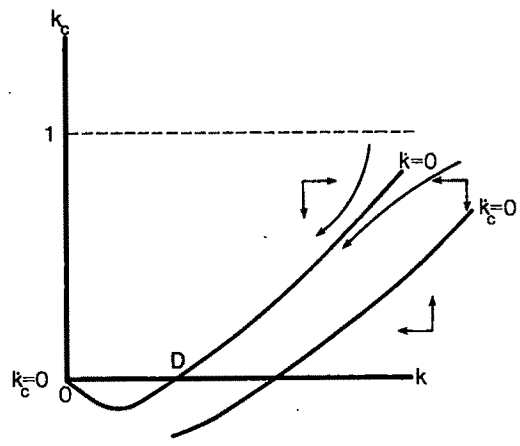

FIGURE 3

ng string of equalities will arise when the case obtains represented by Figure 2:

$$r=Y_k(k^*)=g/s_c. \tag{35}$$

The result $r=g/s_c$ is known as the "Pasinetti paradox" because it indicates that the long-run value of the rate of profit can be characterized independently of the wage earners' propensity to save.

In Figure 3 only the Dual equilibrium exists. In Figure 4 both the Dual and Pasinetti equilibria exist, but the P point lies in an infeasible region of the diagram. Regardless, in both cases, it is the Dual equilibrium that is now dynamically stable. The Dual is the equilibrium discovered by Samuelson and Modigliani (1966) where the rentier class no longer receives any income—and presumably ceases to exist.[7] At such a steady state the system becomes qualitatively similar to the single saving propensity Solow (1956) model. In this case the solitary saving rate is that of wage earners, s_w. The significance of this case is the possibility of a long run where workers receive the entire national income.[8] This case will arise if the rentiers' saving propensity is sufficiently low relative to labor's so that all income eventually flows toward the wage earners.[9]

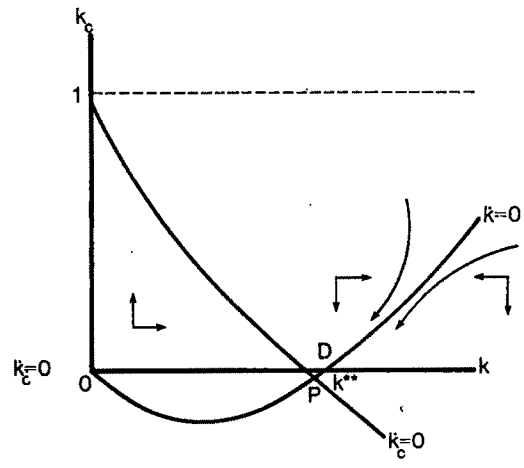

FIGURE 4

[7]Although Samuelson and Modigliani (1966) are usually credited with discovery of the Dual equilibrium, apparently the same result—also under the assumptions of neoclassical growth—was reached independently by James Meade and Kazuo Sato.

[8]The outcomes in Figures 3 and 4 appear to suggest the emergence of an efficient labor-managed economy. Harcourt describes it as "a bloodless revolution in which socialism is ushered in..." (1972, fn. 10 p. 221). Solow, however, has said in conversation that Harcourt is mistaken in ascribing a big social-political significance to all this because $\dot{k}_c=0$ could just as easily be interpreted as Henry Luce's "people capitalism." Of course, all these sorts of disputes hang on defining capitalism in terms of

At the Dual equilibrium, as noted immediately above, the only relevant saving propensity is the wage recipients' fixed saving rate, s_w. (See Kaldor, 1966, p. 33, and John Conlisk and R. Ramanathan, pp. 444–45.) Samuelson (1977) doubts the empirical significance of such an outcome, prompting him to question the "real world" relevance of the Pasinetti system. Peter Drucker, on the other hand, might argue that this outcome follows from the operation of pension funds. All this plunges one headlong into the hoary but important distinction between "ownership" and "control." (See, for example, W. A. Lewis, pp. 331–38.)

The steady-state profit rate at the Dual will be

$$r = Y_k(k^{**}) \tag{36}$$

where $k = k^{**}$ solves

$$a(k, 1) = g/s_w. \tag{37}$$

As noted above, the steady-state rate of profit becomes a virtual mirror image of the rate of profit associated with the Pasinetti equilibrium for now it depends solely on labor's propensity to save.

C. *Synthesis of Kaldor and Pasinetti*

Staying on neoclassical terrain, the most general version of the Cambridge saving equation permitting both rentier and corporate capitalists' saving rates to differ from that of wage recipients leads to only one qualitative outcome. Recall that the integrated K-P system is characterized fully by equations (19) and (20).

In a neoclassical world where earners of income from capital have two faces—rentiers and corporations—the results of growth narrow drastically from those obtained in the pure Pasinetti system. Immediate inspection of the second equation, (20), reveals that inclusion of corporate saving eliminates the branch of the $\dot{k}_c = 0$ locus associated with the Dual equilibrium in the pure Pasinetti system. In the integrated K-P system there is no Dual equilibrium, even under a neoclassical imputation. Moreover, the Pasinetti paradox value of the rate of profit also goes by the boards with the more general saving equation.

Phase diagrams will again be helpful in illustrating the dynamic properties of this system. Again a k_c, k phase space is employed. Begin by determining the shape of the $\dot{k} = 0$ locus. When the capital-total labor ratio becomes stationary the following condition must hold:

$$k_c = \frac{g - s_w(a - Y_k) - s_w(1 - s_p)Y_k - s_p Y_k}{(s_c - s_w)(1 - s_p)Y_k}. \tag{38}$$

Differentiating (38) with respect to k and simplifying yields the following result:

$$\frac{dk_c}{dk} = \frac{-\{s_w(a_k - Y_{kk}) + s_w(1 - s_p)Y_{kk} + s_p Y_{kk}\}}{(s_c - s_w)(1 - s_p)Y_k} - \frac{Y_{kk}}{Y_k}k_c; \tag{39}$$

which is unambiguously positive for nonnegative and "small" negative values of k_c. This means that the $\dot{k} = 0$ locus must be positively sloped in the relevant range of the phase space.

Characteristics of the $\dot{k}_c = 0$ locus are a bit more difficult to ascertain. (Details are con-

---

exchange relations rather than production relations.

[9]Again, use of a Cobb-Douglas production function where $y = k^\alpha$ and $0 < \alpha < 1$ fixes the functional distribution of income. However it does not fix, a priori, the division of ownership of the capital stock between rentiers and workers, which is the object of attention in the Pasinetti system. With a Cobb-Douglas production function a reduced-form expression for the long-run equilibrium capital intensity is

$$k^* = (g/s_c\alpha)^{1/(\alpha-1)}. \tag{a}$$

Given (a) the reduced-form expression for the long-run equilibrium rentier share of the capital stock is

$$k_c^* = (s_c\alpha - s_w)/\alpha(s_c - s_w). \tag{b}$$

When $s_c\alpha \leq s_w$ the system will tend toward the Dual equilibrium; when $s_c\alpha > s_w$ the system will tend toward the Pasinetti point. As observed above, the smaller the rentiers' saving propensity relative to the workers, the more likely that the Dual equilibrium will be attained.

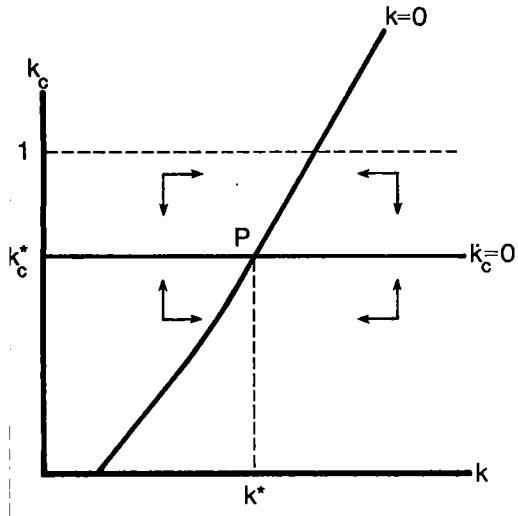

FIGURE 5

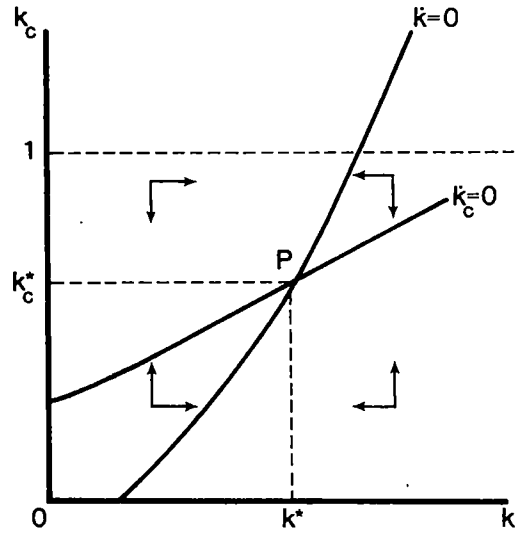

FIGURE 6

tained in a mathematical appendix, available from the author upon request.) In the case when the production function takes Cobb-Douglas form, the $\dot{k}_c=0$ locus will be horizontal in k_c, k phase space and lie between the $k_c=0$ and $k_c=1$. Therefore, as is shown in Figure 5, only the Pasinetti type of equilibrium will exist and it will be globally stable.

With more general forms of the production function (for example, a variable elasticity of substitution production function) the $\dot{k}_c=0$ locus could be either positively or negatively inclined in the relevant region of the phase space. This will not alter the qualitative results (see Figure 6). Again only the Pasinetti type of equilibrium will emerge as the result of long-run growth. The associated rate of profit in this system's long run is not, however, the Pasinetti Paradox value. Rather it is[10]

$$(40)\quad r=Y_k(k^*)=g/\left[s_c(1-s_p)+s_p/k_c^*\right]$$

Still, in the Cobb-Douglas case, k_c^* can be determined independently of the equilibrium capital intensity, k^*, so there is a partial dichotomy. Nevertheless the merger of Kaldor and Pasinetti saving behavior eliminates the paradox insofar as k_c^* depends directly on the workers' saving propensity.[11]

II. Keynesian Growth and the Cambridge Saving Equation

Amartya Sen once outlined a typology of growth models where the neoclassical and Keynesian models were distinguished by the former's closure by marginal product factor pricing and the latter's closure by inclusion of an independent investment function. The discussion that follows is in the same vein.

One of the major themes of Keynes' *Treatise on Money* was the importance of the separation of the decision to save from the decision to invest:

> Saving is the act of the individual consumer and consists in the negative act of refraining from spending the whole of his current income on consumption.
>
> Investment, on the other hand, is the act of the entrepreneur whose function it is to make the decisions which determine the amount of the non-available

[10]When the production function takes Cobb-Douglas form and $s_p=.8$, $s_c=.5$, $s_w=.4$, and $\alpha=.5$, k_c^* will be approximately 50 percent. If $g=.01$ the long-run equilibrium rate of profit will be almost 1 percent.

[11]What cannot be determined directly from the system examined here is the division of the capitalists' share of the capital stock between the rentiers and the corporations.

> output, and consists in the positive act of starting or maintaining some process of production or of withholding liquid goods. It is measured by the net addition to wealth whether in the form of fixed capital, working capital or liquid capital. [1930, p. 172]

The analysis pursued here is more consistent with Keynes of the *Treatise* than Keynes of *The General Theory*. It is Keynes of the *Treatise* who is close to Wicksell of *Geldzins und Guterpreise*, the work where Wicksell presented his famous theory linking the interest rate on money and the aggregate price level.

Wicksell's emphasis on the relationship between the interest rate and the general price level required elaboration of a theory of inflation. To simplify development of the Keynesian growth model here, it will be assumed that prices are fixed, so that the analysis focuses on a setting where there is a 1930 type of Keynes' unemployment. This means that the nominal interest rate and the real interest rate on money always will be the same. The Fisherian distinction need not be made between the real and nominal interest rate on money.

What is the relationship between the rate of profit on capital and the rate of interest on money? Keynes' discussion postulates that the rate of profit faithfully follows movements in the money rate of interest. The rate of profit is a real return on capital and that return—like that of any other asset—moves toward equality with the real return on lending money. Why Keynes believed this to be the case is not clearly stated in *The Treatise* but asserted on *ex hypothesi* grounds. His rationale does not appear until chapter 17 of *The General Theory*, where he elaborates his essential properties of money. For consistency with Keynes' overall approach in *The Treatise*, this assumption will be maintained in the presentation of this Keynesian growth model.

A simple monetary growth model is presented here. Even with this simple model the theory of growth and distribution becomes quite complex. The neoclassical approach guarantees that secular distribution follow the dictates of marginal productivity theory by asserting that marginal product factor pricing applies in the short run. Long-period marginal product factor pricing arises by short-period assumption. No such short-period assumption is made in the Keynesian model. Therefore, it is possible to inquire about whether the system will generate marginal product factor pricing in the long run.

In part to conserve space and in part for theoretical consistency, the discussion that follows will be limited to an analysis with the pure Pasinetti system. Moreover, the specification of the investment function will be as close to neoclassical as one can go to demonstrate that even then the Keynesian approach produces some decidedly nonneoclassical secular results.

Suppose the rate of growth of the capital stock is determined by the flow of investment, I, per unit of existing capital. Suppose further that such an investment relation takes the following form:

$$\dot{K}/K = I/K = I(k, n, r); \qquad I_k<0,\ I_n>0,\ I_r<0. \tag{41}$$

The specification in (41) follows the spirit of a "Tobin q" investment function: investment is positively related to the marginal product of capital which falls as the capital intensity rises. However, the marginal product of capital depends positively upon the employment rate, which accounts for the positive sign of the derivative with respect to n. Finally, investment is inversely related to the return on capital, r, that must be paid out by firms to owners of the capital stock.

This specification of an investment function means conducting the analysis within a world where all capitalists are rentiers. Otherwise, if corporations engage in investment out of retained earnings, the sign of r will be ambiguous. This conforms to Keynes' (1930) strict separation between saving as a household activity and investment as an entrepreneurial activity.

All this is tantamount to arguing that investors compare the gain in output they will achieve from installing an additional unit of

capital against the price they must pay to rent the additional unit from its owners. Investment decisions follow a myopic optimization process due to the Keynesian condition of pervasive subjective uncertainty. Firms act based upon knowledge of the current capital intensity and the current real return on capital (or "rate of profit" *payable* to capital owners).[12] For example, conceive of households renting capital to firms by lending finance through their savings via financial intermediaries.

In this sort of Keynesian world the rate of return on capital is tied in monotonic fashion to the money rate of interest. Consequently if the money rate adjusts to clear the goods market, it is equally legitimate to treat the return on capital as playing the equilibrating role.

Myopia on the part of investors is not consistent with continuous full employment. Nor is continuous full employment consistent with Keynes' research. So although the real return on capital adapts to clear the goods market, it does not necessarily do so at full employment. The root source of other than full employment in the Keynes-Wicksell approach is thus an inappropriate "factor price." With such an inappropriate price and a historically given endowment of capital determined by prior sequences of accretions to the capital stock, goods market equilibrium is brought about in the short term by an adjustment in the employment of labor.

Investment per unit of capital is specified fully by (41). Saving per unit of capital is given by the expression below:

$$S/K=s_w a(k,n)+(s_c-s_w)rk_c. \tag{42}$$

Goods market equilibrium will now require:

$$I(k,n,r)=s_w a(k,n)+(s_c-s_w)rk_c. \tag{43}$$

[12]If one needs "microeconomic foundations" for the sort of investment behavior depicted here where uncertainty about the future plays an important role can be discerned, see especially Kenneth Arrow. Deep, subjective uncertainty is not emphasized by Keynes until *The General Theory* where he speaks of "the dark forces of time and ignorance which envelop our future" (p. 155). But a Tobin q investment function is still quite distant from sheer "animal spirits."

Since in the short run, k is fixed and the real return on capital, r, is pegged by whatever value the prevailing money rate of interest takes, the employment rate is the variable that adjusts to maintain goods market equilibrium. By the implicit function theorem, the employment rate will depend on the capital intensity, the rentiers' share of the capital stock, and the profit rate:

$$n=n(k,k_c,r) \tag{44}$$

Total differentiation of (43) provides the following expression for the signs of the partial derivatives of the employment rate function:

$$\partial n/\partial k=(s_w a_k-I_k)/(I_n-s_w a_n); \tag{45}$$

$$\partial n/\partial k_c=(s_c-s_w)r/(I_n-s_w a_n); \tag{46}$$

$$\partial n/\partial r=((s_c-s_w)k_c-I_r)/(I_n-s_w a_n). \tag{47}$$

The expressions in (45), (46), and (47) are ambiguous. If saving elasticities are greater than investment elasticities, then the partial derivatives of the employment function take the following signs:

$$n_k>0;\ n_{k_c}<0;\ n_r<0. \tag{48}$$

The assumption of the *relative* insensitivity of investment to changes in the model's variables is the conventional assumption made to give the *IS* curve its negative slope in interest rate-output space in the standard short-run income-expenditure model.

The employment rate function can then be substituted back into the investment function to obtain:

$$I(k,n,r)=I[k,n(k,k_c,r),r]. \tag{49}$$

But this means that investment per unit of capital is now really a function of the variables k, k_c, and r so that the function can be rewritten to depend on those three arguments. We thus introduce a new function J such that

$$I/K=J(k,k_c,r). \tag{50}$$

Given (49), the partial derivatives of the J function are equivalent to

$$J_k = I_k + I_n n_k; \tag{51}$$

$$J_{k_c} = I_n n_{k_c} < 0; \tag{52}$$

$$J_r = I_r + I_n n_r < 0. \tag{53}$$

Both (52) and (53) are unambiguously negative in sign, while the sign of (51) is ambiguous because I_k is negative while I_n and n_k are positive. The sign of J_k will be considered more fully below when the stability analysis is examined.

Now most of the tools are assembled for a look at the nature of Keynesian growth and distribution. In the steady state, capital accumulation must proceed at the same rate as the natural growth rate:

$$\dot{k}/k = \dot{K}/K - \dot{L}/L = J(k, k_c, r) - g = 0. \tag{54}$$

The accumulation relation for the rentier class that must be satisfied in the steady state is

$$\begin{aligned} \dot{k}_c/k_c &= \dot{K}_c/K_c - \dot{K}/K \\ &= s_c r - J(k, k_c, r) = 0. \end{aligned} \tag{55}$$

All that need be introduced is a differential equation that specifies the stationarity condition for the real return on capital. The return on capital is sticky in the short run because it must match the real rate of interest on money. The latter does not always correspond to the full-employment rate. If the monetary authorities lower the money rate of interest in response to a condition of unemployment then the real return on capital falls to attain full employment. Assume here that the rate of profit falls when employment is "too low" as a stimulus to aggregate demand and rises when employment is "too high" to dampen effective demand. It ceases to change when the system is at full employment. Thus this simple model assumes that all influences on the money rate of interest are negligible *except* changes in the money supply. Monetary policymaking is "endogenous" following a simple feedback rule based upon employment fluctuations.

Therefore in the steady state the following condition must hold:

$$\dot{r} = \gamma[n - 1] = 0; \quad 0 < \gamma < \infty. \tag{56}$$

γ can be called a "reaction-response coefficient" that captures how rapidly the money rate of interest, and subsequently the real return on capital, changes when the economy is away from full employment.

The complete system appears below with the conditions for dynamic equilibrium:

$$\dot{k} = [J(k, k_c, r) - g]k = 0; \tag{57}$$

$$\dot{k}_c = [s_c r - J(k, k_c, r)]k_c = 0; \tag{58}$$

$$\dot{r} = \gamma[n(k, k_c, r) - 1] = 0. \tag{59}$$

If Pasinetti's type of equilibrium exists there is some combination of values $(k, k_c, r) = (k^{**}, k_c^{**}, g/s_c)$, where $0 < k_c^{**} < 1$, that solves the system. If the Samuelson-Modigliani Dual equilibrium exists, there is some combination of values $(k, k_c, r) = (k^*, 0, r^*)$ that solves the system. Evaluation of the dynamic properties of this system is considerably more difficult than in the neoclassical case because now there is a third equation of a third dimension of motion. To make any headway in investigating the stability properties of this model it is necessary to suppose equilibria exist and linearize about them. For details on the stability analysis, a mathematical appendix is available upon request.

The Pasinetti equilibrium will be associated with a situation where $J = g = s_c r$ and $n = 1$. The rate of investment equals the rate of population growth which equals the rate of growth of capital accumulation by the rentier class; plus full employment obtains at a Pasinetti steady state.

At the Dual equilibrium $J = g$ and $n = 1$ but the rate of investment need not equal the rate growth of rentier capital. It can be shown (see the mathematical appendix) that while the rentier share of the capital stock is obvi-

ously smaller—since it is zero—at a D point than it is at a P point, the rate of profit will be higher. This means in turn that at a Dual equilibrium $(s_c r^* - J)$ is positive.

If the derivative of the investment function with respect to the capital intensity, J_k, is positive, the steady-state capital-labor ratio will be lower at the D point than it is at the P point. If J_k is negative, the steady-state capital intensity will be higher at the D point than at the P point.

Moreover, if J_k is positive in sign local stability is ruled out for the Dual equilibrium anyway. The keys to distinguishing between the local stability of each of the potential steady states are primarily the magnitude of the rentiers' saving rate, s_c, and the sign and magnitude of the derivative J_k. Higher values of s_c and a positive sign of J_k contributes to stability of the Pasinetti equilibrium. Smaller values of s_c and a negative value of J_k contribute to the stability of the Dual equilibrium. For the Dual equilibrium to be locally stable, in fact, the absolute value of the elasticity of investment with respect to the capital intensity must exceed the absolute value of the elasticity of investment with respect to the profit rate.

When the Pasinetti equilibrium does not exist—when there is no solution for the system where $k_c > 0$—it relaxes the condition that $(s_c r^* - J) > 0$ at the Dual. This will expand the set of parameters for which stability of the Dual can obtain.

There is, in addition, another interesting possibility. Suppose there is a Pasinetti-type of solution to the system $(k^{**}, k_c^{**}, r^{**})$ such that k_c^{**} *exceeds* unity. The P point exists but it is economically infeasible due to the constraint $0 < k_c < 1$. But if the infeasible equilibrium satisfied the local stability conditions, the system could grow along a time path where rentiers continually accumulate capital and workers continually decumulate in per capita terms. Thus an *anti-Dual outcome* is also potentially present under a Keynesian approach to the Pasinetti model, a case of perpetual disequilibrium where the rentier share of the capital stock tends toward, without ever reaching, unity.

This means that the Keynesian version of the Pasinetti system, under different parameterizations, can lead to any of the three possible secular results: either rentiers and workers eventually own fixed shares of the capital stock, workers eventually own the entire capital stock and the rentiers disappear, or the rentiers come to own an ever-increasing share of the capital stock. The Pasinetti equilibrium, the Dual equilibrium, and the anti-Dual permanent disequilibrium case are all possible under Keynesian growth.

Unlike the neoclassical version of the Pasinetti system, existence and stability of the steady state are not inextricably linked. When the Pasinetti equilibrium exists under neoclassical growth it is the steady state which the economy tends toward; when only the Dual equilibrium exists under neoclassical growth, it is dynamically stable. Under Keynesian growth these simple conclusions no longer apply. The precise character of the investment function is critical. Furthermore, there is no reason why the Dual equilibrium must always exist, while it must in the neoclassical version of Pasinetti's model.

In advance of knowledge of the system's parameters there is no reason to anticipate reaching the Pasinetti Paradox rate of profit or perpetual full employment. Roy Harrod's (1939, 1973) long-run instability problem glares out plainly once investment can vary with some independence from the volume of saving.[13] In a Keynesian context, Harrodian instability is a problem even if the monetary authorities act to alter the real rate of interest on money and thereby the real return on capital. What matters is how rapidly their response becomes effective which hangs on the size of γ.

And what about the secular profit rate in a Keynesian world of this sort? If either a Pasinetti or Dual equilibrium is attained, what will be the characteristics of the long

[13] Harrod's concerns about the dynamic instability of growing capitalist economies did not arise, as is commonly thought (see Solow, 1956) because of a belief in the technical impossibility of substitution between capital and labor. Rather Harrod's concerns stemmed from a belief that the future is uncertain, consequently investment is highly volatile, and in addition, relative factor prices are fairly rigid in the short term (see Harrod, 1973 and Hywel Jones).

run rate of profit?[14] In general, it will *not* equal the marginal product of capital. It is clear that even with one of the simplest of monetary growth theories the theory of distribution becomes complicated quite rapidly.

[14]Suppose the investment function is given the following simple linear specification:

$$\text{(a)} \quad I/K = c + b\cdot(Y_k - r); \quad 0<b<\infty, 0<c<\infty;$$

where c is a constant level of autonomous investment and b is a constant multiplicative factor capturing the responsiveness of investment activity to the gap between the marginal product of capital and the rate at which firms can borrow capital. If the production function is Cobb-Douglas, the long-run equilibrium rate of profit at a P point becomes

$$\text{(b)} \quad r^{**} = \frac{(c-g)+\alpha b(k^{**})^{(\alpha-1)}}{b} = g/s_c$$

since full employment prevails at the steady state. The long-run rate of profit will satisfy the Pasinetti Paradox value but it will not equal the marginal product of capital unless by some fortuitous chance the autonomous component of investment happened to equal the population growth rate, or $c=g$. The reduced form expression for k^{**} at a P point will be:

$$\text{(c)} \quad k^{**} = \left[\{bg + s_c(g-c)\}/\alpha b s_c\right]^{1/(\alpha-1)}.$$

If $g=.01$, $c=1$, $s_c=.3$, $b=50$, and $\alpha=.5$ the long-run equilibrium capital intensity would be approximately 13.7 and the long-run equilibrium rate of profit would be about 33 percent. To get a "clear" solution for the rentiers' steady-state share of the capital stock would require derivation of a precise specification of the employment function, a difficult task not undertaken here.

The steady-state rate of profit can permanently differ from the marginal product of capital when investors only gradually adjust to the q gap due to their inability to accurately preceive tomorrow. If the parameter b equalled infinity for example, it would plunge the analysis back into the neoclassical world, even with an independent investment function. In general, though, the Keynesian approach liberates secular distribution from marginal productivity theory.

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Productivity Growth, Scale Economies, and Capacity Utilization in U.S. Railroads, 1955–74

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Numerous studies, including Robert Solow and Dale Jorgenson and Zvi Griliches, have emphasized the importance of distinguishing between movements along a production function and shifts in a production function. Such shifts have been given various labels including productivity growth, technological change, and technical progress. In this paper we refer to the shift of a production function as productivity growth. Estimates of productivity growth, and hence attempts to distinguish productivity growth from movements along the production function, depend heavily on the assumptions made regarding the structure of production and the behavior of the firm.

Studies of productivity growth typically assume that observed data reflect a constant returns to scale structure of production and static equilibrium for the firm. If these assumptions are violated, then estimates of productivity growth include the effects of scale economies and movements toward or away from equilibrium, in addition to shifts in the structure of production. The first objective of this paper is to propose methodology for obtaining estimates of productivity growth that do not reflect changes in scale and movements toward or away from equilibrium. Our first task in developing this methodology is to provide an unambiguous definition of productivity growth. In particular we seek a definition that permits us to study productivity growth in the case of a general structure of production with multiple inputs and multiple outputs. The second task in our methodological development is to demonstrate how the measurement of productivity growth can be approached from either the primal or the dual characterization of the production structure, even when some inputs are not employed at static equilibrium levels.

The second objective of this paper is to apply our methodology to obtain estimates of productivity growth for Class I U.S. railroads in the period 1955–74. This application is attractive because the assumptions of constant returns to scale and static equilibrium have both been questioned for U.S. railroads in the postwar period. Numerous Class I railroads were so small that they were unlikely to have exhausted available scale economies by 1955. In the following years some of these railroads grew substantially, both via increases in freight traffic and via mergers and consolidations, and thus had the possibility of exploiting economies of larger firm size. It is widely believed that U.S. railroads have operated with substantial excess capacity. The recent growth in freight traffic has been accompanied by abandonment of track, which suggests that the railroads have been moving in the direction of static equilibrium.

Our estimates of productivity growth are derived from estimates of the railroad cost structure. There is a well-established tradition of using cost function analyses to model the railroad industry. This practice is predicated on the fact that railroads are common carriers. They are required to accept all traffic at rates approved by the Interstate Commerce Commission, and hence their output levels can be taken as exogeneous. In our application we use the multiproduct variable cost function to estimate the structure of railroad production. Use of the variable cost function permits us to specify that railroads may be in disequilibrium with respect to

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their stocks of way and structures. We use the generalized translog functional form, proposed by Caves, Christensen, and Michael Tretheway, to represent the variable cost function. This form imposes no restrictions on the degree of returns to scale in the production structure. We estimate the parameters of this cost function using cross-section data from 1955, 1963, and 1974. The implied estimates of productivity growth for the typical Class I railroad are 3.5 precent per year, 1955–63, and .6 percent per year, 1963–74. For the full 1955–74 period we estimate an average annual rate of productivity growth of 1.8 percent per year.

For comparison we have also estimated productivity growth under the assumption of static equilibrium. Under the specification of static equilibrium, the estimate of productivity growth for the full 1955–74 period is .9 percent per year. The 1955–63 and 1955–74 estimates are 1.0 and .5 percent per year, respectively.

I. Methodology

The transformation function for a general structure of production can be written

(1)

$$F(\ln Y_1, \ldots, \ln Y_m, \ln X_1, \ldots, \ln X_n, t) = 1;$$

where the Y_i are outputs, the X_i are inputs, and t is time. The total differential of (1) is

(2) $$\Sigma F_{Yi}\, d\ln Y_i + \Sigma F_{Xi}\, d\ln X_i + F_t dt = 0,$$

where the F_{Yi} are partial derivatives of F with respect to the $\ln Y_i$, etc. In the single output case, productivity growth is typically defined as the rate at which output can grow over time with inputs held constant: $\partial \ln Y/\partial t$. With multiple outputs the natural generalization is to define productivity growth as the common rate at which all outputs can grow over time with inputs held fixed (hereafter referred to as PGY): $d\ln Y_i/dt = d\ln Y_j/dt$; $d\ln X = 0$. In terms of partial derivatives of the transformation function we have $PGY = -F_t/\Sigma F_{Yi}$.

In the multiproduct case, it is just as natural to define productivity growth as the common rate at which all inputs can be decreased over time with outputs held fixed (hereafter referred to as PGX): $-d\ln X_i/dt = -d\ln X_j/dt$; $d\ln Y = 0$. In terms of partial derivatives of the transformation function we have $PGX = F_t/\Sigma F_{Xi}$.

It is straightforward to show that PGY and PGX are related by the degree of returns to scale (RTS) in the transformation function.[1] Defining RTS as the proportional increase in all outputs resulting from a proportional increase in all inputs with time fixed, we have $RTS = -\Sigma F_{Xi}/\Sigma F_{Yi}$. This implies that $PGY = RTS \cdot PGX$.

Thus, our alternative definitions of productivity growth are equivalent if and only if $RTS = 1$, in which case the transformation function exhibits constant returns to scale in the region where productivity growth is being evaluated.

If the firm minimizes cost with respect to all inputs, and there is a convex input structure, then there exists a total cost function, dual to (1), which can be written

(3)

$$\ln CT = G(\ln Y_1, \ldots, \ln Y_m, \ln P_1, \ldots, \ln P_n, t),$$

where the P_i are the prices of the X_i and $CT = \Sigma P_i X_i$.[2] From knowledge of the cost function we can infer the structure of the transformation function. In particular, comparative statics analysis à la Paul Samuelson implies the following relationships between the derivatives of (1) and (3):

(4) $$\partial \ln CT/\partial \ln Y_i = -F_{Yi}/\Sigma F_{Xi},$$

(5) $$\partial \ln CT/\partial t = -F_t/\Sigma F_{Xi}.$$

Summing (4) over outputs provides the formula for computing returns to scale from the total cost function:

(6) $$RTS = (\Sigma(\partial \ln CT/\partial \ln Y_i))^{-1}.$$

[1]See William Baumol, and John Panzar and Robert Willig for discussion of returns to scale in the multiproduct case.

[2]See Daniel McFadden.

From (5) and (6) it follows that $PGX = -\partial \ln CT/\partial t$ and $PGY = -(\partial \ln CT/\partial t)/(\Sigma(\partial \ln CT/\partial \ln Y_i))$.[3]

If the firm does not minimize cost with respect to all inputs, the total cost function (3) does not exist. However, if the firm minimizes the cost of a subset of inputs (variable factors) conditional on the levels of the remaining inputs (quasi-fixed factors) then there exists a "variable" cost function:

$$(7)\quad \ln CV = H(\ln Y_1, \ldots, \ln Y_m, \ln P_1, \ldots, \ln P_{n-q}, \ln Z_1, \ldots, \ln Z_q, t),$$

where $CV = \Sigma_{i=1}^{n-q} P_i X_i$ and the Z_i represent quasi-fixed factors, that is, the subset of the X_i that is difficult to adjust. The variable cost function (7), like the total cost function, provides all the information required to infer the structure of production.[4] In particular, comparative statics analysis implies the following relationships between the derivatives of (1) and (7):

$$(8)\quad \partial \ln CV/\partial \ln Y_i = -F_{Yi}/\Sigma F_{Xi},$$

$$(9)\quad \partial \ln CV/\partial \ln Z_i = -F_{Zi}/\Sigma F_{Xi},$$

$$(10)\quad \partial \ln CV/\partial t = -F_t/\Sigma F_{Xi}.$$

Combining these relationships with the expressions for RTS, PGY, and PGX yields:

$$(11)\quad RTS = (1 - \Sigma(\partial \ln CV/\partial \ln Z_i))/\Sigma(\partial \ln CV/\partial \ln Y_i),$$

$$(12)\quad PGY = -(\partial \ln CV/\partial t)/(\Sigma \partial \ln CV/\partial \ln Y_i),$$

$$(13)\quad PGX = -(\partial \ln CV/\partial t)/(1 - (\Sigma \partial \ln CV/\partial \ln Z_j)).$$

The formulas for productivity growth from the total cost function and the variable cost function coincide when the firm minimizes total cost. This can be demonstrated by noting that minimization of total cost requires $\partial \ln CV/\partial \ln Z_i = -P_i Z_i/CV$, and that $(CV/CT)(\partial \ln CV/\partial t) = \partial \ln CT/\partial t$.

II. Estimation of the Structure of Production and Productivity Growth in U.S. Railroads using the Variable Cost Function

Our sample consists of cross sections of Class I railroads for 1955, 1963, and 1974, with 58, 56, and 40 firms, respectively. There are four output indexes: (i) ton-miles of freight, (ii) average length of freight haul, (iii) passenger-miles, and (iv) average length of passenger trips. There are three variable input indexes: (i) labor, (ii) fuel, and (iii) equipment (and materials). We specify that way and structures capital is a quasi-fixed factor in the variable cost function. Estimates of the stock of way and structures for the individual railroads are available from the Interstate Commerce Commission (ICC).[5]

We employ the generalized translog multiproduct-cost function to represent the variable cost function. This generalization of the translog form involves using the Box-Cox metric rather than the natural *log* metric for output levels.[6] This permits the inclusion of firms with zero passenger output—which is inadmissible for the translog form. Using Y_i to denote the Box-Cox transformation of output y_i, $Y_i = (y_i^{\lambda} - 1)/\lambda$, and K to denote the Box-Cox transformation of way and structures capital k, $K = (k^{\lambda} - 1)/\lambda$, we write the generalized translog variable cost function for railroads:

$$(14)\quad \ln CV = \alpha_0 + \sum_i^4 \alpha_i Y_i + \alpha_K K + \sum_i^3 \beta_i \ln P_i + \tfrac{1}{2}\sum_i^4 \sum_j^4 \delta_{ij} Y_i Y_j + \tfrac{1}{2}\delta_{KK} K^2 + \tfrac{1}{2}\sum_i^3 \sum_j^3 \gamma_{ij} \ln P_i \ln P_j + \sum_i^4 \sum_j^3 \rho_{ij} Y_i \ln P_j + \sum_j^3 \rho_{Kj} K \ln P_j + \sum_j^4 \theta_{Kj} K Y_j.$$

[3]See M. Ohta for discussion of the latter relationship in the single output case.

[4]See Lawrence Lau, who treates both (3) and (7) as normalized restricted profit functions.

[5]Stock estimates for the beginning of 1955 and 1963 are available in the ICC's *Elements of Value*. These figures have been updated to 1974 by Robert Nelson.

[6]The translog multiproduct cost function is discussed by David Burgess, and Randall Brown, Caves, and Christensen.

The estimation of (14) with pooled data from 1955, 1963, and 1974 would be undesirable because it would not allow for differences among the years in the structure of production. On the other hand, with data only for three widely spaced years it would be undesirable to introduce the usual integer measure of time. We overcome this problem by introducing binary variables for 1955 and 1974 (for example, $D_{55}=1$ in 1955, zero elsewhere) which allow the structure of production to be different from that of 1963. These binary variables are allowed to interact with the output and way and structures indexes and the input prices. The variable cost function augmented by these binary variables can be written

$$(15)\quad \begin{aligned} ln\,CV = {} & \alpha_0+\alpha_{55}D_{55}+\alpha_{74}D_{74} \\ & +\sum_i Y_i(\alpha_i+\alpha_{55i}D_{55}+\alpha_{74i}D_{74}) \\ & +K(\alpha_K+\alpha_{55K}D_{55}+\alpha_{74K}D_{74}) \\ & +\sum_i ln\,P_i(\beta_i+\beta_{55i}D_{55}+\beta_{74i}D_{74}) \\ & +\tfrac{1}{2}\sum_i\sum_j \delta_{ij}Y_iY_j+\tfrac{1}{2}\delta_{KK}K^2 \\ & +\tfrac{1}{2}\sum_i\sum_j \gamma_{ij}ln\,P_i\,ln\,P_j \\ & +\sum_i\sum_j \rho_{ij}Y_i\,ln\,P_j+\sum_j \rho_{Kj}K\,ln\,P_j \\ & +\sum_j \theta_{Kj}KY_j. \end{aligned}$$

Without loss of generality we impose symmetry on the γ_{ij} and δ_{ij}. For our application this results in (15) having 63 parameters to be estimated. We impose the theoretical requirement of homogeneity of degree one in input prices, using the following linear restrictions:

$$(16)\quad \Sigma\beta_i=1,\ \Sigma\beta_{55i}=0,\ \Sigma\beta_{74i}=0,$$
$$\sum_j \gamma_{ij}=0\ \forall_i,\ \rho_{Kj}+\sum_j \rho_{ij}=0.$$

These restrictions reduce the number of parameters to be estimated from 63 to 52. Given the large number of parameters in (15) to be estimated, it is desirable to make use of the following cost share equations implied by Ronald Shephard's Lemma:

$$(17)\quad \begin{aligned} P_iX_i/CV=S_i=\beta_i+\beta_{55i}D_{55} & \\ +\beta_{74i}D_{74}+\sum_j \gamma_{ij}ln\,P_j & \\ +\sum_j \rho_{ij}Y_j+\rho_{Ki}K; \quad i=1,\ldots,n-q. & \end{aligned}$$

We treat (15) and (17) as a multivariate regression system and proceed to obtain efficient estimates of the parameters using a modification of the technique proposed by Arnold Zellner.[7] The estimated parameters are presented in Table 1, along with their standard errors.[8]

The theory of cost and production requires that the own-price elasticities of the variable factors be negative and that the Hessian matrix, $[\partial^2 CV/\partial P_i\partial P_j]$, be negative semidefinite. We find that the parameter estimates in Table 1 satisfy these regularity conditions for every railroad in all three cross-section years. In Table 2 we present the own-price elasticities and the Allen cross elasticities of sub-

[7]To avoid the problems created by singularity of the contemporaneous covariance matrix, we delete one of the share equations prior to carrying out the second stage of Zellner's technique. The resulting estimates are asymptotically equivalent to maximum likelihood estimates, as well as being invariant to which equation is deleted at the second stage.

[8]The y_i and P_i were normalized such that the mean of the 1963 values is equal to unity. In estimating the parameters of (15) we considered various restrictions on the structure of cost. There were two hypotheses which could not be rejected when tested jointly: 1) the elasticities of cost with respect to the outputs and fixed factor are independent of time, $\alpha_{55I}=\alpha_{74i}=\alpha_{55K}=\alpha_{74K}=0$; and 2) the length of haul of one output does not affect the cost elasticity of the other output or the cost elasticity of the length of haul of the other output, $\delta_{TR}=\delta_{PH}=\delta_{RH}=0$ (subscripts as defined in Table 1). Relaxation of these restrictions results in estimates that are less stable but qualitatively unchanged. To estimate (15) we have used a value for λ of 0.1. Caves, Christensen and Tretheway have provided evidence that estimates and standard errors of other parameters are generally insensitive to varying values of λ around 0.1.

TABLE 1—ESTIMATED PARAMETERS FOR THE GENERALIZED TRANSLOG VARIABLE COST FUNCTION

Coefficient	Estimate	Standard Error	Coefficient	Estimate	Standard Error
α	18.8037	.0293	ρ_{TL}	−.0074	.0170
α_{55}	.2195	.0323	ρ_{TE}	.0076	.0031
α_{74}	−.0318	.0432	ρ_{TQ}	−.0001	.0174
α_T	.5723	.0560	ρ_{HL}	−.0406	.0145
α_H	−.1117	.0473	ρ_{HE}	.0069	.0026
α_P	.1584	.0235	ρ_{HQ}	.0338	.0145
α_R	−.0239	.0205	ρ_{PL}	.0002	.0044
δ_{TT}	.1417	.1885	ρ_{PE}	−.0013	.0008
δ_{HH}	−.1349	.1375	ρ_{PQ}	.0010	.0046
δ_{PP}	.0214	.0140	ρ_{RL}	−.0015	.0033
δ_{RR}	−.0178	.0189	ρ_{RE}	.0015	.0006
δ_{TH}	.1804	.1254	ρ_{RQ}	−.0000	.0033
δ_{TP}	−.0073	.0124	β_{L55}	.0803	.0168
δ_{PR}	.0090	.0110	β_{L74}	−.1202	.0306
α_K	.2646	.0698	β_{E55}	.0130	.0030
δ_{KK}	.2417	.2246	β_{E74}	.0229	.0054
β_L	.5531	.0091	β_{Q55}	−.0932	.0169
β_E	.0408	.0017	β_{Q74}	.0973	.0316
β_Q	.4061	.0093	ρ_{KL}	.0268	.0196
γ_{LL}	.1610	.0589	ρ_{KE}	−.0059	.0036
γ_{EE}	−.0075	.0045	ρ_{KQ}	−.0209	.0201
γ_{QQ}	.1826	.0602	θ_{KT}	−.2212	.1931
γ_{LE}	.0146	.0095	θ_{KH}	−.1332	.1160
γ_{LQ}	−.1755	.0588	θ_{KP}	−.0143	.0262
γ_{QE}	−.0070	.0095	θ_{KR}	.0069	.0138

Note: T=ton-miles; H=length of haul; P=passenger-miles; R=length of trip, K=structures, L=labor, E=fuel, Q=equipment-materials; 55=1955, 74=1974.

TABLE 2—OWN-PRICE ELASTICITIES AND ELASTICITIES OF SUBSTITUTION FROM THE ESTIMATED VARIABLE COST FUNCTION FOR U.S. RAILROADS[a]

	Own-Price Elasticities			Elasticities of Substitution		
	Equipment	Labor	Fuel	Equipment-Labor	Equipment-Fuel	Labor-Fuel
1955	−.13	−.13	−1.10	.17	.60	1.49
1963	−.14	−.16	−1.14	.22	.58	1.65
1974	−.15	−.18	−1.04	.18	.76	1.42

[a]Evaluated at the average firm for each year.

TABLE 3—ELASTICITIES OF VARIABLE COST EVALUATED AT THE AVERAGE FIRM IN EACH CROSS-SECTION YEAR

	Elasticity of Variable Cost with Respect to:				
	Ton-Miles	Average Freight Haul	Passenger-Miles	Average Passenger Trip	Structures
1955	.612	−.113	.170	−.008	.208
1963	.605	−.138	.151	−.009	.235
1974	.716	−.093	.123	.006	.143

titution for the three variable factors, valuated for the average firm.[9]

Evaluation of productivity growth, (12) nd (13), requires estimates of the elasticities f variable cost with respect to the output ndexes and the stock of way and structures. These five elasticities are presented for the verage firm for each of the three cross section years in Table 3. The degree of scale conomies can be computed from these elasicities using (11). These estimates are presented in Table 4 for the average firm in ach cross-section year. These estimates, denoted *RTS*1, are based on equiproportional ncrease of all four output indexes. This implies that increases in ton-miles and passenger-miles are entirely due to increased distance with fixed tonnage and numbers of passengers. The alternative extreme would be to define scale economies with ton-mile and passenger-mile increases resulting entirely from tonnage and passenger increases with distance fixed. This is accomplished by using only the ton-mile and passenger-mile cost elasticities in evaluating (11). These alternative estimates of the degree of scale economies are denoted by *RTS*2 in Table 4. Scale economies could also be defined to reflect any desired combination of increases in distance as well as increases in tonnage and passengers. In this case the degree of scale economies would fall between the two sets of estimates in Table 4.

[9]The average firm is defined as follows:

	Ton-Miles (billions)	Average-Haul (miles)	Passenger-Miles (millions)
1955	9.98	275	400.4
1963	10.59	291	266.9
1974	19.92	342	191.1
	Average-Trip (miles)	Structures (millions 1963 $)	
1955	96.	479	
1963	84.	652	
1974	26.	717	
		Input Prices	
	Equipment	Labor	Fuel
1955	.783	.653	.874
1963	1.000	1.000	1.000
1974	1.479	2.321	2.828

TABLE 4—ESTIMATES OF RETURNS TO SCALE FROM THE VARIABLE COST FUNCTION

	1955	1963	1974
*RTS*1	1.196	1.257	1.142
	(.075)	(.088)	(.075)
*RTS*2	1.012	1.012	1.036
	(.028)	(.029)	(.040)

Note: *RTS*1 assumes that proportional increases in ton-miles and passenger-miles are due entirely to increases in average haul and trip length. *RTS*2 assumes no increases in average haul and trip length. Standard errors are in parentheses.

The first step in evaluating productivity growth according to either equation (12) or (13) is to evaluate the shift in the variable cost function with respect to time, $\partial \ln CV/\partial t$. Time does not enter our cost functions directly; it is represented by the binary variables D_{55} and D_{74}. Thus we measure the shift in the cost function between years r and s as

$$\partial \ln CV/\partial t = (\ln CV(r) - \ln CV(s))/(r-s), \tag{18}$$

where $\ln CV(k)$ is the variable cost function evaluated with the binary variables set at appropriate values for year k. In evaluating $\ln CV(r)$ and $\ln CV(s)$ all variables other than the binary variables are held fixed at the means of the values for the representative firms for years r and s.[10] The first row of Table 5 presents our estimate of the shifts in the cost function between each pair of years. We have presented these estimates as average annual percent growth rates by multiplying the results of (18) by 100.

The remaining rows of Table 5 present measures of productivity growth. When productivity is defined according to constant output levels we obtain the estimated growth rates shown in row 2 of Table 5. In the case where inputs are held constant we compute productivity growth using the two alternative estimates of scale economies from Table 4.

[10]Our method for evaluating $\partial \ln CV/\partial t$, including the use of the means of the representative firms, can be viewed as an application of the quadratic approximation lemma. See W. Erwin Diewert.

TABLE 5—AVERAGE ANNUAL RATE OF PRODUCTIVITY GROWTH ESTIMATED FROM THE VARIABLE COST FUNCTION[a]

	1955–74	1955–63	1963–74
Shift in variable cost function	1.4	2.7	0.5
PGX: Productivity growth—outputs fixed	1.8	3.4	0.6
*PGY*1: Productivity growth—inputs fixed (*RTS*1)	2.0	4.2	0.7
*PGY*2: Productivity growth—inputs fixed (*RTS*2)	1.8	3.5	0.6

[a]Growth rate shown in percent per year.

These estimates of productivity growth are shown in rows 3 and 4 of Table 5. The three alternative estimates all indicate that there was rapid productivity growth from 1955 to 1963, on the order of 3.5 to 4.0 percent per year. From 1963 to 1974 the rate slowed to less than 1 percent per year. Over the full period, productivity growth averaged approximately 2 percent per year.

III. Estimation of the Structure of Production and Productivity Growth in U.S. Railroads Using the Total Cost Function

If the firm minimizes cost with respect to all inputs, including structures, then the correct cost function to analyze the structure of production is the total cost function. In our previous paper on U.S. railroad productivity we presented estimates of a total cost function for U.S. railroads based on the same data set employed in this paper. In this section we use those estimates to infer the structure of production and productivity growth in U.S. railroads. These inferences can then be compared to those from the variable cost function, presented in the previous section.

We begin by comparing the input demand structure for the two estimated cost functions. The own-price elasticities and elasticities of substitution from the total cost function are shown in Table 6. These results are clearly not as satisfactory as those of the variable cost function shown in Table 2. The total cost function yields capital and labor own-price elasticities that are essentially zero. In fact, the point estimate of the capital price elasticity is positive, in violation of the requirements of our cost-minimization model.[11]

In Table 7 we present the cost elasticities implied by the estimated total cost function. In Table 8 we show the returns to scale implied by these cost elasticity estimates. Despite the fact that the variable cost model yields more credible estimates of the input demand structure, both the variable and total cost models produce very similar estimates of scale economies. Both models show fairly strong, statistically significant, scale economies if output increases come in the form of increased haul and trip lengths. Both models show only slight, statistically insignificant, scale economies if output is increased with length of haul and trip held fixed.

In Table 9 we show estimates of productivity growth from the total cost function. The estimates for the full period, 1955–74, are considerably different from the estimates in Table 5 from the variable cost function. The figures for the subperiods reveal that most of this difference arises in the early 1955–63 subperiod: estimates of productivity growth are much higher for the variable than for the total cost function. In the more recent subperiod, 1963–74, both cost functions yield small estimates of productivity growth; however the estimates from the total cost function are again below the estimates from the variable cost function.

Our estimates of productivity growth based on the total cost function are considerably lower than those reported in our previous paper, where we used industry average elasticities to construct index number estimates of aggregate railroad productivity. The primary reason for this difference is the fact that, in our previous paper, we analyzed industry totals rather than firm data. The estimated total cost function implies little shift in the production structure, but strong scale economies. Much of the effect of these

[11]The violation of the regularity conditions is slight. Small adjustments of certain of the cost function parameters would eliminate the problem and have no effect on the cost elasticities and productivity growth estimates, which are our primary interest. See our earlier paper for further discussion.

TABLE 6—OWN-PRICE ELASTICITIES AND ELASTICITIES OF SUBSTITUTION FROM THE ESTIMATED TOTAL COST FUNCTION FOR U.S. RAILROADS

	Own-Price Elasticities			Elasticities of Substitution		
	Capital	Labor	Fuel	Capital-Labor	Capital-Fuel	Labor-Fuel
1955	.01	−.08	−1.09	−.02	−.07	2.24
1963	.02	−.08	−1.17	−.03	−.21	3.29
1974	.01	−.09	−1.05	−.06	.30	2.14

TABLE 7—ELASTICITIES OF TOTAL COST EVALUATED AT THE AVERAGE FIRM IN EACH CROSS-SECTION YEAR

	Elasticities of Total Cost with Respect to:			
	Ton-Miles	Average Freight Haul	Passenger-Miles	Average Passenger Trip
1955	.756	−.108	.204	−.025
1963	.765	−.111	.184	−.025
1974	.802	−.110	.154	−.012

TABLE 8—ESTIMATES OF RETURNS TO SCALE FROM THE TOTAL COST FUNCTION[a]

	1955	1963	1974
*RST*1	1.209	1.230	1.199
	(.064)	(.066)	(.075)
*RTS*2	1.042	1.054	1.046
	(.021)	(.021)	(.031)

Note: *RTS*1 and *RTS*2 are defined in Table 4. Standard errors are in parentheses.

TABLE 9—ESTIMATED AVERAGE ANNUAL RATE OF PRODUCTIVITY GROWTH USING THE TOTAL COST FUNCTION[a]

	1955–74	1955–63	1963–74
PGX	0.8	1.0	0.4
*PGY*1	1.0	1.2	0.5
*PGY*2	0.9	1.0	0.5

[a]See Table 5.

strong scale economies on cost is hidden in the industry aggregate data. This is because the industry totals show little output growth and hence little effect of scale; whereas output of the average firm has grown substantially through mergers and consolidations. The scale effects associated with this growth of firm size show up as productivity growth at the industry aggregate level.

IV. Concluding Remarks

The measurement of productivity growth is an attempt to distinguish shifts in the structure of production from movements along the efficient production surface. In this paper we have developed definitions of productivity growth for more general structures of production than have previously been considered. In addition we have showed how to develop measures of productivity growth under a different set of behavioral specifications than have been used in other applications. We have applied our definitions and measurement procedures to data from the U.S. railroad industry for the post-World War II period to obtain new measures of growth in U.S. railroad productivity.

The measurement techniques that we utilize permit the production structure to have any degree of returns to scale. In addition we relax the assumption that the firm

minimizes total cost, and assume instead that the firm minimizes the cost of employing variable factors subject to predetermined levels of quasi-fixed factors. The estimation of productivity growth under these specifications requires econometric estimation rather than index number analysis. We utilize a variable cost function to estimate the structure of production and productivity growth for U.S. railroads.

Our estimates of the variable cost model show that returns to scale are sizeable for U.S. railroads if output changes are accompanied by changes in haul and trip lengths. Since haul and trip lengths have changed substantially during the period we are examining, we conclude that it is important to permit nonconstant returns to scale in the production structure.

We compare the results from our variable cost function to those implied by the total cost function. Although the two cost functions imply similar estimates of returns to scale, they yield different estimates of productivity growth, especially in the early period. We conclude that the behavioral assumptions underlying cost function analysis have important implications for the measurement of productivity growth.

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An Experience-Weighted Measure of Employment and Unemployment Durations

By GEORGE A. AKERLOF AND BRIAN G. M. MAIN*

Kim Clark and Lawrence Summers (1979) have recently established that while most unemployment spells are quite short, most time spent in unemployment is spent in spells of longer than average duration. This apparent paradox is due to the fact that the most common measure of the average length of a spell of unemployment is an average of all spell lengths terminating in a given period, herein labeled S_{TW}. In this measure, all spells are given the same weighting irrespective of the amount of unemployment for which they account. Weighting each spell by its length would result in an experience-weighted measure, herein labeled S_{EW}, which would reflect the length of spell in which a typical week of unemployment is spent and, hence, avoid the Clark and Summers paradox.

Our paper motivates this alternative measure, S_{EW}, and observes that in the steady state a reasonable measure of this experience-weighted spell duration is twice the official Bureau of Labor Statistics (*BLS*) average duration of uncompleted spells, herein labeled T. When this approach is applied to employment statistics, in the form of job tenures, a sharp contrast is found between the average length of a job as reflected in turnover statistics or the terminations-weighted spell length, S_{TW}, and as measured by the experience-weighted average job duration, S_{EW}. It appears that although the average job is of short duration, most employment is spent in jobs of longer than average duration.

The fact that both employment and unemployment fall in spells of considerably greater length than is indicated by examination of turnover statistics, is of considerable import to the standing of what has come to be known as the "new view" of the labor market. (See Martin Feldstein; Robert Hall; George Perry.) In this view the labor market is full of movement with both employment and unemployment occurring in relatively brief spells. That there is a lot of movement is a fact reflected in labor market turnover statistics. As our empirical work will show, however, it is erroneous to take these turnover statistics which reflect average movement through certain states to reflect the average experience of persons in these states. In both employment and unemployment there appears to be much more permanence than the new view allows. In our view, for most purposes, the existence of many short spells of employment or unemployment is of little relevance if these spells in the aggregate contribute relatively little, respectively, to total employment or total unemployment. This appears in fact to be the case since employment-years and unemployment-weeks are in spells which are on average quite long.

Section I will explain theoretically and by analogy the meaning of the various measures of average spell lengths and present some facts about their relationship to each other. Section II displays estimates both of the length of the average completed spell and of the experience-weighted completed spell length for various populations for job tenures and unemployment durations. Section III contains some concluding remarks pertaining to the ramifications of these results on labor market policy.

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I. Three Different Measures of Spell Length

A. *Three Statistics Defined and Explained with Use of a Diagram*

The different measures of durations statistics can be most easily explained by reference to Figure 1 (which is adapted from a similar diagram by Stephen Salant). Let the horizontal lines in Figure 1 represent the periods during which persons (labeled on the vertical axis) are unemployed. (An exactly analogous figure could be drawn for job tenures.)

Now consider three possible measures of unemployment duration. The first measure is the one commonly reported. Suppose that at date t_0 a poll is taken which records how long the persons who are unemployed at t_0 have been out of work. In terms of the diagram, Person 1 has been out of work for a length of time T_1, Person 2 for a length of time T_2, Person 5 for a length of time T_5, and Person 6 for a length of time T_6. Persons 3 and 4 are not out of work, and therefore their unemployment durations are not recorded in the sample. An average computed from the durations out of work of those unemployed at time of interview would thus be

$$T=(T_1+T_2+T_5+T_6)/4.$$

This statistic T corresponds to the official statistics on mean duration of unemployment reported by the *BLS*.

There is at least one sense in which this statistic is lacking. The times T_1, T_2, T_5, and T_6 do not report the completed length of the spells of persons 1, 2, 5, and 6, respectively, but only the length of their interrupted spell, which is for each person an obviously shorter phenomenon. In terms of the diagram, the average completed length of unemployment spells of the currently unemployed is

$$S_{EW}=(S_1+S_2+S_5+S_6)/4.$$

S is Salant's notation for completed length of spell. The subscripts EW stand for "experience-weighted" spell length, as shall be explained presently.

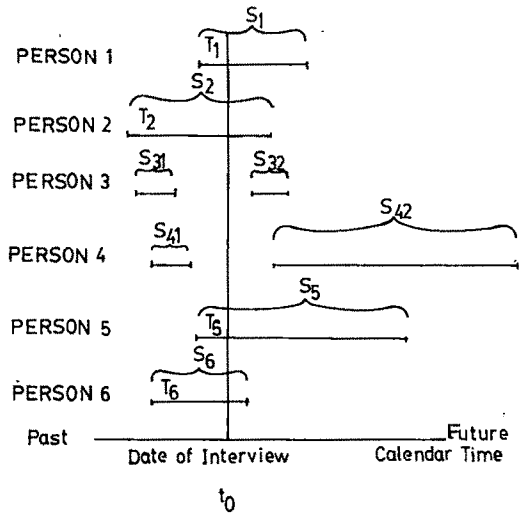

FIGURE 1

On the other hand, there is yet a third measure of the average length of unemployment. This measure consists of the average length of all spells of unemployment, where the spells are not defined to be those in progress at a given point in time, as in S_{EW}, but are those spells which are observed to terminate over a given period of time. In such an average each spell counts exactly once, irrespective of its total contribution to unemployment. In terms of Figure 1 such an average would be

$$S_{TW}=(S_1+S_2+S_{31}+S_{32}+S_{41}+S_{42}+S_5+S_6)/8,$$

taking into account the two repeat spells of persons 3 and 4. This statistic is represented by the symbol S_{TW}, where TW mnemonically represents "termination-weighted." The time period over which these terminations have been averaged in the literature has commonly been the calendar year (see Hyman Kaitz and Salant).

In contrast to S_{TW}, which weights all spells equally, the chances of sampling a given spell at a given point in time is proportional to its length. For this reason in steady state the average of completed spells at a given point in time (t_0 for example) is equivalent to a

measure which weights spells according to their contribution to total unemployment; this contribution is, of course, their completed length. It was for this reason that the measure $S_{EW}=(S_1+S_2+S_5+S_6)/4$ was named the experience-weighted spell length.

B. *Explanations of Three Statistics by Analogy*

An analogy is exact and also gives intuitive explanation of the three statistics. Barring the repeat spells of Persons 4 and 5, Figure 1 could be taken to represent not the length of time unemployed, but, instead, the life spans of persons over some period of time, with Person i having a life span of length S_i, with life beginning and ending in calendar time as indicated by the horizontal lines. The statistic T corresponds to the average *age* of the population; the statistic S_{EW} corresponds to the average *life span* of the population alive at t_0, and S_{TW} corresponds to the average life span of all persons who die over some period of time, or, equivalently in a steady state, is life expectancy at birth. The latter statistic is smaller than the former because longer-lived persons are more apt to be seen in any given census; thus the person who dies at eighty is visited by eight decennial censuses; the child who dies at ten is seen by only one decennial census. In demography, life expectancy at birth (S_{TW}) is dramatically different from the average life expectancy of a population (S_{EW}) where there are high rates of child mortality. The dramatic differences reported in the next section between S_{EW} and S_{TW} for job tenures and unemployment durations are the similar result, caused by the existence of many short job tenures and of many short spells of unemployment.

C. *A Numerical Example*

A numerical example illustrates the relation between the two statistics S_{EW} and S_{TW}, and how it may come about that S_{EW} may be long while S_{TW} is short.

Suppose that there are two persons who are continuously employed over a ten-year period. The first is employed in ten consecutive jobs with each job lasting exactly one year. The second person, however, is employed in the same job for the entire ten-year period. At any moment of time a census of this population will find two persons employed. One person will be in a one-year job; the other will be in a ten-year job. The average completed job tenure of the currently employed is, accordingly, five and one-half years. Furthermore, it should be apparent, perhaps after a moment's reflection, that, since in each and every year the average length of job in which that year's employment is spent is five and one-half years, so it is also true that over the entire period the average length of job in which employment is spent is five and one-half years.

On the other hand, in the example there are eleven spells of employment that terminate over the period and twenty employment years. Thus $S_{TW}=20/11\cong 1.8$. The measure S_{EW} weights the ten one-year jobs equally with the one ten-year job, according to their respective contributions to employment. In contrast, S_{TW} weights all eleven spells equally.

D. *Interpretation of Data in Steady State*

Censuses enumerate populations at given moments of time. It is a central question in demography to use population censuses to calculate mortality tables that show average life expectancy at birth, or S_{TW}. Similarly, the Bureau of Labor Statistics produces monthly data on the length of interrupted spells of unemployment and occasional tables on the interrupted job tenure of workers (see *BLS*, 1964, 1967, 1969, 1974). This paper uses these census-like data to infer both the average experience-weighted and the average termination-weighted unemployment durations and job tenures.

A property of the steady state permits empirical estimates of S_{EW} from reported statistics on interrupted spells. In the steady state a person who is interviewed at a random time will be interviewed with uniform probability throughout the length of his spell. Thus for each person i, $E(T_i)=S_i/2$, and with a large population $S_{EW}=2T$. This fact

TABLE 1—ESTIMATED MEAN COMPLETED TENURE OF CURRENTLY HELD JOBS (IN YEARS)=S_{EW}

	Male				Female			
	1963	1966	1968	1973	1963	1966	1968	1973
A. By Race, Date, and Sex								
White	17.4	18.2	18.3	17.2	11.6	12.1	11.6	11.1
Nonwhite	14.2	14.1	14.4	14.2	11.0	11.6	10.3	11.8
B. By Industry, Date, and Sex								
Agriculture	24.5	28.2	29.0	30.6	22.9	28.6	23.3	23.0
Mining	19.4	18.5	20.7	19.7	–	–	–	–
Construction	10.5	11.0	12.3	11.9	10.0	12.1	9.4	10.2
Manufacturing—durable	18.8	21.8	18.3	18.3	13.2	14.1	12.2	13.2
Manufacturing—nondurable	18.3	19.8	19.5	18.5	13.7	14.5	14.0	13.7
Transport/public utilities	21.8	23.4	22.8	20.6	16.4	16.1	15.1	13.3
Wholesale/retail	11.7	12.2	13.7	11.7	9.2	9.3	9.1	8.7
Service/finance	12.0	11.8	13.7	11.5	9.8	10.2	9.9	10.2
Public Administration	18.6	19.4	18.8	19.3	14.5	13.2	12.7	12.7
C. By Occupation, Date, and Sex								
Professional/technical	16.2	17.1	16.7	16.3	13.2	13.9	13.1	12.3
Managers, proprietors	21.2	22.1	22.0	19.7	17.3	19.4	18.1	16.4
Clerical and kindred	17.0	17.2	17.2	16.9	11.0	11.1	10.6	10.4
Sales workers	12.4	13.8	14.1	14.2	10.5	10.3	10.2	8.7
Craftsmen, foremen	18.4	20.0	19.5	18.2	14.6	17.4	16.8	14.0
Operatives and kindred	15.7	15.6	15.7	15.0	13.4	13.8	12.7	13.1
Nonfarm laborers	11.4	11.3	12.7	10.9	–	13.6	14.1	9.1
Farm laborers and foremen	9.7	11.4	10.7	13.5	23.6	27.3	24.0	23.3
Service workers	12.8	12.8	13.3	11.6	8.4	9.8	8.7	9.4

Source: See text.

gives a simple way of estimating the S_{EW} statistic, using the steady-state assumption, from the official *BLS* statistics on interrupted spells.

II. Job Tenures and Longest Job-Unemployment Durations

This section, among other things, displays estimates of the two statistics on job tenures and unemployment durations S_{EW} and S_{TW}, for various populations. It shows that S_{EW} is empirically a uniformly large multiple of S_{TW} both for job tenures and for unemployment durations.

A. *Job Tenures*

The Bureau of Labor Statistics has, on occasion, compiled data on interrupted job tenures. Table 1 displays the estimated mean completed tenure of currently held jobs for a variety of demographic, occupational, and industrial subgroups. Assuming the steady state, we doubled an estimate of the mean interrupted job tenure to give the statistic reported in Table 1 as S_{EW}, or the estimated mean completed tenure of currently held jobs. The estimates were found to display a remarkable stability for each subgroup over time; this stability for four different times, not all at the same phase of the business cycle, gives some confidence in the use of the steady-state assumption to calculate S_{TW} and S_{EW}.

Table 2 reports the estimates obtained using the steady-state assumption for mean completed job tenures in the 1968 to 1973 period and compares them with the estimated experience-weighted job tenures for 1968 as obtained in Table 1.[1] These statistics support the major hypothesis of this paper: that the average employment-year is spent in a job of long tenure even though the average length of all jobs is quite short. For white males the estimated average completed length of job is four years; however, the average length of job of currently employed males is

[1]See our 1979 article.

TABLE 2—ESTIMATED MEAN COMPLETED TENURE (IN YEARS) OF JOBS HELD IN JANUARY 1968 = S_{EW}; ESTIMATED MEAN COMPLETED TENURE (IN YEARS) OF JOBS ENDING BETWEEN JANUARY 1968 AND JANUARY 1973 = S_{TW}; AND THE RATIO OF S_{EW}/S_{TW}

	Male			Female		
	S_{EW}	S_{TW}	S_{EW}/S_{TW}	S_{EW}	S_{TW}	S_{EW}/S_{TW}
A. By Race and Sex						
White	18.3	3.9	4.7	11.6	2.6	4.5
Nonwhite	14.4	2.8	5.1	10.3	2.2	4.7
B. By Industry and Sex						
Agriculture	29.0	3.6	8.1	23.3	3.8	6.1
Mining	20.7	4.8	4.3	–	–	–
Construction	12.3	2.4	5.1	9.4	2.5	3.8
Manufacturing—durable	18.3	4.3	4.3	12.2	3.1	3.9
Manufacturing—nondurable	19.5	4.2	4.6	14.0	3.2	4.4
Transport/public utilities	22.8	5.8	3.9	15.1	3.6	4.2
Wholesale/retail	13.7	2.6	5.3	9.1	2.1	4.3
Service/finance	13.7	3.0	4.6	9.9	2.2	4.5
Public administration	18.8	5.7	3.3	12.7	3.4	3.7
C. By Occupation and Sex						
Professional/technical	16.7	4.0	4.2	13.1	2.7	4.9
Managers, proprietors	22.0	7.3	3.0	18.1	5.8	3.1
Clerical and kindred	17.2	3.6	4.8	10.6	2.6	4.1
Sales workers	14.1	3.0	4.7	10.2	2.4	4.3
Craftsmen and foremen	19.5	4.5	4.3	16.8	4.6	3.7
Operatives and kindred	15.7	3.0	5.2	12.7	2.8	4.5
Nonfarm laborers	12.7	2.4	5.3	14.1	2.7	5.2
Farm laborers and foremen	10.7	1.6	6.7	24.0	4.0	6.0
Service workers	13.3	2.8	4.8	8.7	1.9	4.6

Source: Calculations described in the text.

over eighteen years. For white females the comparable statistics are three and twelve years, respectively.

Relative to the new view of employment, which sees jobs as being of short duration, the eighteen years for male employees and the twelve years for female employees is quite long. Furthermore, although the steady-state assumption is violated due to growth of the labor force, this tends to bias the estimated average downwards, since persons with long employment began their jobs long ago and therefore their fraction, as reported in the *BLS* table of interrupted durations, is less than would occur in a steady state without employment growth. (A calculation reported elsewhere crudely estimates the underreporting bias as 7 percent for women and 4 percent for men.)

Table 2, Panels A and B, report the comparable statistics for employment by occupation and industry. It should again be noted that the S_{EW} statistic is considerably longer than the S_{TW} statistic and, as a rule of thumb, the longer statistic is a multiple three to five times the shorter statistic for the same population subgroup.

B. *Longest Job*

The statistics on job tenures strongly suggest that most adult males do have a "normal" job which they maintain for a good portion of their adult lives. There is one corroborating piece of evidence. In 1966 Parnes' National Longitudinal Survey asked older men 45 to 59 (i.e., with average age 52) about their longest job. As can be seen in Table 3, the average length of longest job was seventeen years. This estimate must be taken as a lower bound since the youngest of these men were still twenty years from retirement age and almost two-thirds reported that they were currently in their longest job. This large fraction is by itself another indicator of the employment stability of most of the adult

TABLE 3—AVERAGE LENGTH (IN YEARS) OF LONGEST JOB BY AGE AND RACE FOR OLDER MALE WORKERS (45–59) IN 1966[a]

Age	All	White	Black
45	14.7	15.2	13.4
46	13.6	13.8	12.9
47	14.4	14.5	14.2
48	15.1	15.3	14.4
49	15.5	15.4	15.6
50	17.3	17.6	16.8
51	16.8	17.2	15.9
52	18.4	18.7	17.8
53	17.6	18.1	16.3
54	18.0	18.8	16.3
55	18.7	19.2	17.4
56	20.0	20.8	18.3
57	21.5	22.4	19.4
58	19.8	21.2	17.7
59	20.5	21.5	17.7
45–59	17.2	17.7	16.1
N	(4817)	(3397)	(1343)

[a]From Parnes' National Longitudinal Study.

male labor force. Finally, we might mention that almost 8 percent of the sample of these older men still found themselves in 1966 in their first job after school.

C. *Unemployment Durations*

Table 4 presents estimates of the two statistics S_{TW} and S_{EW} in columns 1 and 2, respectively. Column 1 is the estimated average length of all spells of unemployment ending over a span of time, by year, for the years 1948–78 for the U.S. population. Column 2 gives estimated average lengths of completed spell of persons unemployed at a given time for the same years, 1948–78, or, equivalently, the average duration of unemployment spell in which an unemployment-week occurs.

For the years 1966 to 1978, S_{TW} was calculated by the method of Salant. His method maximizes the likelihood of the observed breakdown of the observed population into different categories given that interrupted spells are distributed as a beta distribution. Earlier estimates of escape rates are obtained from Kaitz. Estimates of S_{EW} are obtained by employing the steady-state assumption and doubling the mean interrupted spell length T as reported by the *BLS*. It should be noted that for almost all years from 1948 to 1978 the ratio of the two statistics S_{EW} to S_{TW} was between three and five.

Table 4 thus demonstrates what appears to be an empirical regularity: the average duration of all spells of unemployment of a given subgroup of the U.S. population which terminate over the course of a year, S_{TW}, is much shorter than the average duration of the completed spells of those unemployed at any moment in time, S_{EW}; and, as a rule of thumb, the latter statistic is a multiple between three and five of the former statistic. While the average duration of all unemployment spells of the total U.S. population was approximately six weeks, the average duration of completed spell of those unemployed at each moment of time for the United States over the postwar period was approximately six months. The computations made to calculate Table 4, of course, use the steady-state assumption. The sensitivity of our estimates to these assumptions has been examined elsewhere with results generally favorable to the use of these assumptions (see our 1979 article).

III. Conclusion

This paper has presented and shown empirical estimates of a measure of S_{EW} of the average length of a spell in which an employment-year and an unemployment-week is spent. According to estimates in the preceding sections experience-weighted means of job tenures and unemployment durations are, as an empirical regularity, all longer by large multiples (for example, roughly three to five) than the mean length of all jobs and all spells of unemployment.

While the average job may be quite short because there are many short jobs, most employment experience is spent in jobs that are quite long. This is somewhat contrary to the popularized view of the U.S. labor market as one where everyone is on the brink of changing jobs. If an "I quit" was induced at each opportunity of a job paying a few dollars more; or a "you're fired" was forthcoming at every deviation from required productivity,

TABLE 4—WEIGHTED AND UNWEIGHTED UNEMPLOYMENT DURATIONS

	Average Duration (in Weeks) of Completed Spells of Unemployment Unweighted[a]	Estimate of Weighted Average Duration of Completed Spells of Unemployment[b]	Unemployment Rate	
	S_{TW}	S_{EW}		S_{EW}/S_{TW}
1948	4.6	17.2	3.8	3.7
1949	6.2	20.0	5.9	3.2
1950	6.7	24.2	5.3	3.6
1951	4.1	19.4	3.3	4.7
1952	4.0	16.8	3.0	4.0
1953	3.7	16.0	2.9	4.3
1954	6.4	23.6	5.5	3.7
1955	5.4	26.0	4.4	4.8
1956	5.0	22.6	4.1	4.5
1957	5.7	21.0	4.3	3.7
1958	7.4	27.8	6.8	3.8
1959	6.2	28.8	5.5	4.6
1960	6.0	25.6	5.5	4.3
1961	7.2	31.2	6.7	4.3
1962	6.2	29.4	5.5	4.7
1963	6.4	28.0	5.7	4.4
1964	5.8	26.6	5.2	4.6
1965	5.2	23.6	4.5	4.5
1966	4.2	20.8	3.8	5.0
1967	5.0	17.6	3.8	3.5
1968	4.5	16.8	3.6	3.7
1969	4.6	15.8	3.5	3.4
1970	5.4	17.4	4.9	3.2
1971	6.8	22.6	5.9	3.3
1972	6.2	24.0	5.6	3.9
1973	7.0	20.0	4.9	2.9
1974	5.6	19.4	5.6	3.5
1975	9.1	28.2	8.5	3.1
1976	8.0	31.6	7.7	4.0
1977	7.2	28.6	7.0	4.0
1978	6.3	26.2	6.0	4.2

[a]*Source*: Kaitz and our 1980 article.
[b]Double the average durations of unemployment durations of unemployed persons.

currently employed males would hardly be expected to average an eighteen-year job tenure in their current jobs! This popular view that jobs are quite short is, however, a statistical artifact based on an erroneous interpretation of turnover statistics. While there may be less permanence than in previous times, it remains that the average male is in a job of quite long standing. There exists a considerable degree of permanence in the labor market.

If a monthly turnover rate of around 2.8 percent is taken to imply that all jobs last three years, then the opportunities for pay to diverge from marginal product must be limited. If, on the other hand, jobs currently in progress are expected to last an average of eighteen years, there seems to be considerable scope for the existence of internal labor markets and for the pay of most, although certainly not all, to diverge from their respective marginal products. The experience-weighted spell length S_{EW} seems to shed light on possible imperfections in the labor market.

One other practical and immediate example can be given of the explanatory power of experience-weighted job durations. The crisis at Chrysler can be viewed as the traumatic termination of many thousands of jobs. Turnover statistics for the automobile in-

dustry indicate that jobs last on average three years. The male jobs being terminated at Chrysler, however, if they are of the same length as in the rest of manufacturing industry, have an expected tenure of around twenty years. This is altogether a more serious situation.

On the subject of unemployment, it is apparent that while the average unemployment spell may be quite short because there are many short spells of unemployment, most unemployment experience is spent in spells that are quite long. For the application of economic theory to the problems of unemployment, the less misleading statistic to our mind is not the length of the average spell of unemployment but, rather, the average length of spell in which time unemployed is spent. The existence of many short spells is of little consequence if the very shortness of these spells means that they do not contribute much to total unemployment. The measure S_{EW} with respect to unemployment shows that most time spent unemployed is in spells that are quite long.

This observation on unemployment is not new, and has been made most forcibly by Clark and Summers (1979) who effectively derive a Gini coefficient for the distribution of unemployment. Our measure S_{EW} lacks the sophistication of the Clark and Summers' approach, and must be viewed as an easily derived summary measure. Examination of Table 4 indicates that in the late 1970's the typical week of unemployment was spent in a length in excess of six months. This result can only add weight to Clark and Summers' rejection of both search theory and the theory of contracts as plausible explanations of unemployment. Remedies for unemployment must clearly be aimed at "the unemployed" rather than at making the labor market more efficient.

In summary, the use of estimates of the experience-weighted spell length S_{EW} that were easily derived from the observed interrupted spell lengths T of stocks of both the employed and the unemployed, has led to a view of the U.S. labor market that is distinctly stock-oriented or "long." The source of confusion created by the use of turnover statistics or their equivalent, termination-weighted average spell lengths S_{TW} has been explained. The respective views of the U.S. labor market provided by these two types of measure are remarkably different. From a policy viewpoint it seems important to emphasize that examination of turnover in labor market states can lead to a mistaken short view of the labor market stemming from estimates of low S_{TW}; while examination of labor market participants leads, in fact, to a long view of the labor market through remarkably high values of S_{EW}.

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William Jaffé, Historian of Economic Thought, 1898–1980

By DONALD A. WALKER*

During his lifetime William Jaffé was recognized by all economists as the leading authority on the work of Léon Walras. It is through Jaffé's translation of Walras's *Eléments d'économie politique pure* that English-speaking persons are able to study Walras's model of general economic equilibrium. It is by reference to Jaffé's (1965a) monumental edition of Walras's correspondence and related papers that scholars are able to gain insights into the evolution of Walras's economics. It is by studying Jaffé's writings that the work of Walras becomes more intelligible, placed within its historical context, and illuminated by an explanation of its genesis.

I. Education and Early Career

In retrospect it can be seen that Jaffé's concentration upon a nineteenth-century French neoclassical economist was a logical outcome of the course that his education eventually followed and of his early career. He was born in Brooklyn on June 16, 1898, the only child of immigrant Russian Jewish parents, who imbued him with a conviction of the importance of scholarship and of the rightness of pacifism, socialism, and religious agnosticism. Entering the City College of New York in 1915, he graduated summa cum laude with a Bachelor of Arts in English and Classics on June 20, 1918. The following September he began graduate studies at Columbia University, completing an M.A. degree in History in 1919. Under the influence of Henri Marie Lafontaine, a Belgian lawyer and Nobel Peace Prize winner whose course on international law he had taken as an undergraduate, Jaffé then decided to pursue the study of that subject at the doctoral level at Columbia, but discovered that he was handicapped by a lack of modern languages. He therefore formed the plan of spending a year in Europe.

Jaffé arrived in France in May of 1921, and began to study international law at the University of Paris. Soon thereafter he met Grace Mary Spurway, an Englishwoman who was also a student, and married her in Paris in January of 1922. That marriage resulted in a daughter in 1933 and twin sons in 1935, but it was eroded by differences of personality and interests, and ultimately ended in divorce. At the University of Paris, Jaffé progressed rapidly in learning French and in his coursework, but when France sent troops to invade the Ruhr in 1923 he came to the conclusion that there was no hope that pacifism would be adopted as a policy by the nations of the world, and lost his motivating force for studying international law. Largely because of his interest in socialism, Jaffé decided instead to study economics, and, beginning his lifelong mission of communicating the ideas of one culture to the members of another, wrote a dissertation on Thorstein Veblen in French (1924b). Jaffé was awarded the degree of *Docteur en Droit ès sciences économiques et politiques* in June of 1924.

The following year he was hired by Carlton J. H. Hayes, the Columbia University historian, who had arrived in France to direct a study of its postwar condition. Jaffé was assigned to collaborate with William Ogburn, with whom he coauthored *The Economic Development of Post-War France*. Then he needed a permanent position, and in 1928, aided by the recommendation of Wesley Claire Mitchell, obtained an assistant professorship at Northwestern University, with the duty of teaching Marshall and the Continental economists to graduate students. Shortly after arriving at Northwestern, Jaffé struck up a friendship with Henry Schultz, the University of Chicago economist, who was also a City College graduate. Schultz has an im-

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ɔortant place in the filiation of events and nfluences that led Jaffé to concentrate on Walras. It is difficult for us today to realize hat most economists in the 1920's either cnew nothing about Walras or considered iim a minor figure, a "non-Austrian founder ɔf the Austrian School."[1] Indeed, it takes an effort of historical perception to see that it is o a considerable extent Jaffé's work that has elevated Walras in our consciousness to the ɔosition of a leading neoclassical theorist. Schultz was familiar with Walras's theories, ınd he subsequently published a number of ırticles dealing with them (for example, Schultz, 1929, 1932). It was Schultz who showed Jaffé that Walras was not merely a levotee of cumbersome mathematical notaion and a proponent of eccentric proposals ıbout the nationalization of land and moneary reform; and it was under the stimulus ɔrovided by Schultz's grasp of economic theɔry and his enthusiasm for Walras that Jaffé ɔegan to read the *Eléments* in 1929, became convinced that it should be translated, and ɔegan to work on that task.

While laboring over the book, Jaffé found hat many of its passages seemed obscure, ɔut almost nothing had been published in explanation of Walras to which he could urn. Jaffé had been struck by the way that iis understanding of Marshall's *Principles* vas improved by a study of Marshall's letters Pigou), and it occurred to him that the correspondence of Walras might serve a simiar purpose, enabling him to decipher the *Eléments* with greater ease. After some initial ruitless searches he finally unearthed a vast ıoard of Walras's correspondence and papers ıt the University of Lausanne in 1934, and rom that time onward Jaffé's life turned ıpon Walras's work.

II. Published Contributions

Jaffé's published contributions to economcs can be divided into those which deal with Walras, and those which do not. Among the latter are his works on Veblen and on French economic development, his views on the English translation of Pareto (1972b, 1974a), discussions of other writers' papers delivered at meetings (1932, 1934, 1938, 1948), a note on mathematical economics (1950), an inquiry into the origins and character of Edgeworth's contract curve (1974c, d), a note on the origin of the concept of the opposite circular flows of money and commodities (1975a), and some book reviews (1924a, 1954, 1956b, 1963, 1974b). It is for his work on Walras, however, that he was recognized and honored during his life, and for which he will be remembered. This work is constituted of three major parts, which, taken as a whole, form a well-rounded body of Walrasiana that includes a presentation of Walras's writings, factual information about his life and times, exegesis, and analysis.

First, there is Jaffé's translation of the *Eléments*, the publication for which he is best known. The superlative quality of the translation and the usefulness of its annotation will ensure Jaffé a permanent place in the history of economic thought. Second, there is the superbly edited and annotated three-volume *Correspondence of Léon Walras and Related Papers*.[2] This is a rich source of material on Walras and on the biographical, bibliographical, scientific, social, and economic aspects of his century that are relevant for understanding the genesis of his work and the development of neoclassical economics.[3] Third, there are Jaffé's essays on Walras, in which he treated most of the important themes in Walras's work and many of the questions that can be asked about his life and his impact on economic thought. Since the essays are Jaffé's own writings, as distinct from materials that he edited or translated, it is interesting to examine specifically what they contribute to our knowledge of Walras. They can be divided according to their contents into five major categories.

First, one of Jaffé's major contributions in his essays was to piece together an account

[1]This bizarre judgment, which could have been ɔunded only upon unfamiliarity with Walras's work, vas made by Alexander Gray (p. 341) in a footnote in vhich he remarked that Walras "must be crowded out" f the text for lack of space.

[2]These volumes include the parts of Walras's correspondence that Jaffé had earlier published in journals (1935a, 1952).

[3]For a detailed discussion of the contents of the *Correspondence*, see my earlier article.

of Walras's life, using his papers and letters, his autobiographical statement, government records, and information provided by members of Walras's family. Jaffé went to great effort to uncover the facts of Walras's life and to organize them in relation to his theoretical contributions and policy proposals, in the belief that biography is a scientifically valuable part of the history of economics. Jaffé's major published statement of this thesis was made in an article (1965b) that illustrated its argument by reference to the particular case of Walras, and set forth the themes that animate so much of Jaffé's work: that the scientific interests, outlook, and argument of an author are expressions of his personality, inescapably affected by the influences, both personal and intellectual, to which he has been subjected; and that biography throws light on the meaning as well as on the genesis of theory.

Developing these themes, Jaffé traced (1935b, 1956a, 1968, and *passim* in Jaffé's publications) Walras's unsuccessful attempts to earn a living in a variety of ways in France in the 1860's, his intellectual life during the period from 1858 to 1870, his efforts to learn mathematics and his championing of its use in economics, his view of the relation of economics and statistics, his development of marginal utility theory, and his formulation of general equilibrium theory during the twenty-two years that he taught at the University of Lausanne. As another aspect of Walras's biography, drawing as he so often did upon the seemingly inexhaustible mine of information provided by Walras's correspondence and papers, Jaffé examined Walras's relations with Pareto, Barone, Jevons, Marshall, Edgeworth (1935b), and various American economists (1960), making clear that Walras appreciated and benefited from his American and Italian acquaintances, in contrast to his increasingly antagonistic relationships with the English. Jaffé also recorded Walras's unsuccessful attempts to act as an applied economist by advising governments on specific policy matters (1975b).

Second, in many of his publications Jaffé studied the origins of Walras's theoretical work, especially in those which deal with Walras's biography and in articles on the scientific and philosophical sources of Walras's ideas. The most important antecedent, Jaffé contended, was the work of Achylle-Nicholas Isnard, whom Jaffé described (1969) as the progenitor of the Walrasian general equilibrium model. Although Walras did not explicitly acknowledge a debt to Isnard, Jaffé concluded that Walras used Isnard's *Traité des richesses* as a starting point for his own model of exchange and for his ideas on the *numéraire* commodity and the theory of production. Jaffé also explored the circumstances leading up to and attending the appearance of Walras's *Eléments* describing the lack of enthusiasm with which it was greeted by the economics profession and documenting and discussing the influence of the comments of J. L. F. Bertrand, Ladislaus von Bortkiewicz, and Eugene von Böhm-Bawerk on the subsequent four editions of the book (1977c). In examining the philosophical foundations of Walras' work—as it happened, in the context of showing his similarities to Adam Smith—Jaffé (1977a) showed that Walras was inspired by the methodological and scientific vision of Descartes, that he drew upon Newtonian celestial mechanics as an inspiration for the way that social science should be constructed, and that he was influenced in his youth by the natural law philosophy of Grotius and Samuel Pufendorf.

Third, Jaffé provided an overview of the character of Walras's entire scheme of work to establish a setting within which the relation of its parts can be understood. Jaffé (1956a) explained Walras's tripartite conception of economic studies, namely, economic theory; applied economics, or policy formulation on the assumption of given goals; and social economics, or the evaluation of goals and the formulation of desirable goals, which Walras undertook with the guidance of the notions of the principles of justice that he shared with his father.

Fourth, Jaffé made a number of investigations into particular aspects of Walras's theoretical structure. Walras's theory of consumer demand was explored by Jaffé (1977b) through the illuminating procedure of analyzing the Walras-Poincaré correspon

dence on the cardinal measurability of utility, which shows that Walras took great pains to assure himself that he had correctly treated the measurability of utility and the derivation of the demand function. He had been attacked from various quarters for his attempt to use mathematics in connection with utility and demand, so he sought Poincaré's advice as to whether his treatment was legitimate. Jaffé showed that Poincaré's response, in which he demonstrated a remarkable grasp of what is legitimate and desirable in demand analysis, to a considerable extent reassured the anxious Walras.

On several occasions Jaffé analyzed Walras's theory of capital formation, an extremely difficult subject by reason of its complexity and the obscurity of Walras's presentation of it. Jaffé (1942) took the reader through the theory step-by-step and showed that Walras's static system can explain the pricing of old capital goods, but concluded that his attempt to force the essentially dynamic phenomenon of the formation of new capital into a static framework imposes serious limitations upon the theory as an explanation of the real world. Jaffé (1953) also demonstrated that Walras's theory of capital must be studied from the perspective of the general equilibrium model within which it was constructed. In his last thoughts on the topic, Jaffé revised his earlier opinion (1978, 1980a), concluding that Walras was consistent in treating capital within his static model, because he did not introduce actual changes in the quantities of capital goods.

In another special study, Jaffé made a major contribution (1964) to the history of distribution theory by using Walras's papers and letters to throw new light on the subject. The old quarrel about who had the right of priority in the development of marginal productivity theory—about whether Wicksteed and the English were first, and whether they had neglected to acknowledge the contributions of the Continental economists—was finally settled by Jaffé's research. He described the genesis of the modern formulation of the marginal productivity theory, examined Pareto's contribution, showed that Walras was not the first to develop the mathematical statement of the theory, and revealed that Barone should receive most of the credit for that accomplishment.

The topic of Walras's theory of the tâtonnement process as it operated in his models of exchange, production, capital formation, and monetary behavior was analyzed by Jaffé with the objective of describing what Walras wrote, rather than examining the theory through what Jaffé regarded as the distorting lenses of modern interests and mathematical methods. Accordingly, he reviewed recent interpretations, and argued that they were erroneous in fundamental respects (1967). Prompted by disagreement with Michio Morishima and by dissatisfaction with some aspects of his own earlier analysis, Jaffé reexamined the topic in his last article, written in his eighty-second year (1981; also see Jaffé 1978). Once again he was concerned to defend the historical integrity of Walras's work. In complete mastery of his material, writing from the perspective of years of study and with the authority derived from his profound familiarity with Walras, Jaffé exposed the myths that have been attached to Walras's treatment of tâtonnement, and provided a well-documented exposition and explanation of it. Walras's tâtonnement process, Jaffé maintained, was not intended to describe an actual series of adjustments that work themselves out through time, but is instead a metaphorical and unrealistic representation of a quasi-instantaneous operation.

Fifth, not content with presenting the historical Walras, Jaffé assessed his work and evaluated its place in the history of economic science. Examining his role in the marginal revolution of the 1870's, Jaffé argued (1972a) that by using marginal utility to state the conditions of the equilibrium of exchange, rather than confining the concept to the analysis of individual consumption in the manner of Jevons and Menger, Walras began to trace the line of inquiry that leads to modern theory. To determine Walras's place even more precisely, Jaffé (1976) then expanded upon the theme of how he differed from Jevons and Menger. Countless commentators on the history of economic thought have grouped those writers together as the independent developers of fundamentally similar notions. In fact, Jaffé demonstrated,

they differed in important respects not only in their formal treatment of marginal utility and of other economic principles, but also in the objectives of their analytical work.

Jaffé's major novel assessment of Walras's system—an assessment that has yet to be appraised by other economists—was the thesis that his general equilibrium model is not unalloyed positivistic theory, but has a normative bias (1977d, 1980a). This is manifested, according to Jaffé, in Walras's theorem of maximum social satisfaction and in his critical analysis of Hermann Gossen's theory of maximum social gain from trade, which make clear that Walras's model is an axiomatic formulation of an ideal economic system constructed in conformity with the conception of commutative justice that Pufendorf, his mentor, derived from the philosophy of natural law. Jaffé defended Walras by observing that his many critics have neglected this consideration, and that their misconceptions of his work stem in part from a fundamental misunderstanding of what he was trying to do. They have therefore attacked him, Jaffé maintained, for not accomplishing what he did not seek to achieve, and for omitting from his theory what he did not wish to include in it (see also Jaffé 1951).

Evaluating still another aspect of Walras's contributions and importance, Jaffé (1971) emphasized that Walras's general equilibrium model was not intended as a practical guide to policy. Jaffé recognized its value, but he never succumbed to blind adulation of it. For example, in regard to the theory of tâtonnement, Jaffé demonstrated that Walras evaded the problem of how real markets move to equilibrium and failed to show that his model reaches the same equilibrium that real markets achieve. In Jaffé's opinion the most serious limitation of Walras's model is that as a result of its confinement to the static equilibrium of pure competition it cannot be used to understand the laws of change which lead to the development of oligopolistic market structures. Jaffé also argued (1956a, 1971), however, that aspects of Walras's work are valid contemporary economic theory, not exclusively part of the dead past. Precisely because Walras's model is free of institutional characteristics, Jaffé maintained, it can be used to analyze any economy that has market processes, including socialist economies; and it is a useful aid in the construction of soundly framed particular equilibrium models. Jaffé concluded that we should continue to search for an answer to the question of Walras's importance, and that an ongoing search is more important than finding an answer, because it leads to new discoveries.

In summary, Jaffé's achievements were to furnish English-speaking scholars with access to Walras's major theoretical work, to provide a source book of Walrasiana in his edition of Walras's *Correspondence*, and to present in his essays not only a lucid exposition and evaluation of Walras's theories, but also a perceptive history of the circumstances, influences, and sources that were important in their development. Thus Jaffé created an authoritative account of a great economist's contributions and of the path of intellectual discovery that he followed to achieve them.

III. The Last Years

Jaffé retired from Northwestern in 1966, and began a nomadic period, accompanied, as in all his travels, by his wife, Olive Caroline Weaver Jaffé, whom he had married in 1948. He lectured successively at the University of California at Riverside, at Harvard, and at the University of British Columbia. Then in 1970, York University in Canada gave him an appointment of unlimited duration, and his career entered upon a remarkably productive phase which continued until his death at age eighty-two. The long period during which he had had little recognition was succeeded by the golden years of acclaim in which his accomplishments were acknowledged by his fellow economists and by the larger scientific world also. He was named a Fellow of the Econometric Society in 1963, and a Foreign Member of the Royal Netherlands Academy of Sciences and Letters in 1968. In 1974 he was presented with an honorary LL.D. degree by York University. The British Academy named him a Corresponding Fellow in 1977; and in 1978 he was made a *Chevalier* of the *Légion d'Honneur*.

Canada, his adoptive country, which for many years supported Jaffé's research with generous grants, honored him in 1979 by electing him a Fellow of the Academy of Humanities and Social Sciences of the Royal Society. The citation read at his induction ceremony in May of that year praised his work for its brilliant and subtle combination of history and economic analysis, observing that he had become the leading authority on the life and work of Walras, and praising his "beautiful, crystalline translation and authoritative edition of the classic *Elements of Pure Economics*."

In April of 1980, he received his favorite award when his professional colleagues in the history of economic thought, those whose approbation he prized most, honored him as the first Distinguished Fellow of the History of Economics Society in a special ceremony at their annual meeting. Although seriously ill, he insisted on traveling to Harvard University, where the meetings were held. He received the award, and then, in what was to be his final public address, responded by speaking of his lifelong task of revealing the historical Walras. "I am glad," he said, "that labour of this kind is receiving the recognition you are bestowing on it tonight. If this beautiful ceremony encourages others to follow the arduous path of scholarly historical research and interpretation, I shall feel that my efforts have been amply rewarded" (1980b).

He was active to the very end—correcting the proofs of his last two articles, refereeing manuscripts, making detailed comments on papers on Walras which friends and acquaintances continued to send, and, as always, carrying on an extensive correspondence with economists all over the world. During the last eight months of his life, however, his health began to fail, and he found it increasingly difficult to concentrate on the demanding task of organizing his mass of materials on Walras's life in preparation for the biography that he always intended to write but never completed.[4] In early August of 1980 he was hospitalized in Toronto for an extensive examination, and it was discovered that he had cancer. On August 8 he underwent surgery, but his condition subsequently deteriorated, and he died on the night of August 17, 1980.

Jaffé's professional work was distinguished by his indefatigable scrutiny of original source materials, erudition, command of languages, perfection of literary style, and intellectual integrity. His personal relationships were enriched by his warmth, courtesy, and generosity. Although his friends can no longer have the rewarding experience of communicating with him in person, his gentle, good, and scholarly personality lives on in our memories; and, through the medium of the written word that he loved so much, he will always be able to communicate his thoughts to us and to those who never knew him.

[4]During the last twenty-five years of his life Jaffé worked sporadically on organizing materials for a full-scale biography of Walras, which he ultimately titled *The Life and Writings of Léon Walras*. Jaffé began to draft two chapters of it in his late seventies, the first dealing with Walras's antecedents, and particularly with the life of his father, and the second dealing with Walras's childhood and education. These unfinished chapters contain material that is excellent in its authoritativeness, detail, stylistic qualities, documentation, and depth of understanding of the persons with whom they deal and of nineteenth-century France. They are also enriched by wisdom and compassion, as Jaffé, in the fullness of his years, recorded and reflected upon the struggles and adversities experienced by both father and son.

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Sticky Prices and Disequilibrium Adjustment in a Rational Model of the Inflationary Process

By MICHAEL MUSSA*

In many models of price and wage dynamics, rates of price and wage change are influenced both by disequilibrium in the goods and labor markets and by expectations of the future inflation rate. An important innovation in recent models of inflationary expectations is that such expectations are formed "rationally." From the contributions of Stephen Goldman and Fisher Black (1972, 1974), it is known that serious theoretical difficulties are encountered in models that combine rational expectations with the notion that prices are sticky and respond slowly to disequilibrium. The purpose of this paper is to develop a price adjustment rule that circumvents these theoretical difficulties and to analyze the essential economic characteristics of this rule.

To motivate the development of the proposed price adjustment rule, Section I reviews the theoretical difficulties encountered when rational expectations are imposed on disequilibrium models of price and wage dynamics. The proposed price adjustment rule is then derived, in Section II, from a microeconomic model in which there is an explicit cost to changing *individual* prices. Under suitable aggregation assumptions, it is shown that the rate of change of the *general* price level is equal to the expected rate of change of the *equilibrium* price level plus a term that is proportional to the divergence of the general price level from its equilibrium level. Finally, in Section III, it is shown that this adjustment rule for the general price level resolves the theoretical difficulties discussed in Section I, and that only a price adjustment rule with the same mathematical properties is capable of resolving these difficulties.

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I. Theoretical Difficulties with Rational Expectations and Sticky Prices

In theoretical models that assume that prices or wages are sticky and respond slowly to disequilibrium, a popular form of price adjustment rule is

$$(1) \qquad DP=\alpha\cdot(\text{excess demand})$$

where DP is the time derivative of the logarithm of price and "excess demand" is some measure of the extent of disequilibrium between demand and supply. To illustrate the theoretical difficulties that are encountered in attempting to combine this form of price adjustment rule with the assumption that expectations of the future inflation rate are "rational," it is convenient to use the simple model of the inflationary process developed by Philip Cagan.

Suppose that the demand for money is given by

$$m^d=k+P-\eta\cdot\Pi,$$

where m is the *log* of nominal money balances, P is the *log* of the price level, Π is the expected rate of inflation, k represents all of the factors affecting real money demand other than Π, and $\eta>0$ is the semielasticity of the demand for money with respect to Π. Given the *log* of the nominal money supply m, the price level which yields equilibrium in the money market is

$$\bar{P}=m-k+\eta\cdot\Pi.$$

Assuming that the only alternative to holding money is spending on goods and that the pressure of excess demand in the goods market is proportional to $m-m^d$ with a factor of proportionality of β, the rule (1) becomes[1]

[1]Rudiger Dornbusch and I present a model in which excess demand in the goods market is proportional to the excess supply of real balances. Alternatively, it may

$$(2)\quad DP=\alpha\beta\cdot(m-m^d)=\alpha\beta\cdot(\bar{P}-P).$$

One approach to the integration of rational expectations with a process of disequilibrium adjustment is to introduce rational expectations directly into (2). Under certainty, rational expectations require that the expected rate of inflation, Π, equal the actual rate of inflation, DP. Imposing this requirement on (2) yields the differential equation:

$$(3)\qquad DP=\gamma\cdot(z-P),$$

where $z\equiv m-k$ and $\gamma\equiv\alpha\beta/(1-\alpha\cdot\beta\cdot\eta)$. The solution of (3) is

$$(4)\quad P(t)=P(0)\cdot exp(-\gamma\cdot t)+\int_0^t\gamma\cdot z(s)\cdot exp(\gamma\cdot(s-t))ds,$$

where $P(0)$ is the initial value of P that is fixed by past history under the assumption that prices are sticky.

This solution for $P(t)$ is not a satisfactory description of the path of the price level under rational expectations. If $\gamma<0$, then (4) is unstable, and we have the highly unsatisfactory situation that $P(t)$ diverges to infinity, as determined by $P(0)\cdot exp(-\gamma\cdot t)$, regardless of the behavior of $z(s)$. If $\gamma>0$, then (4) is stable, but it is still not satisfactory. The basic problem (when γ is >0) is that even though expectations of the future inflation rate are rational and affect the price level through their effect on money demand, the known future behavior of $z(s)$, for $s>t$, has no effect on $P(t)$. One manifestation of this basic problem is that $P(t)$ does not, in general, converge to its equilibrium value $\bar{P}(t)$, even in the long run. For example, if z grows at a constant rate μ, then the inflation rate DP converges to its appropriate long-run value $D\bar{P}=\mu$, but $P(t)$ does not converge to $\bar{P}(t)=z(t)+\eta\cdot\mu$. Instead, a permanent divergence between $\bar{P}(t)$ and $P(t)$ is required to sustain the long-run inflation rate at $DP=\alpha\beta\cdot(\bar{P}-P)=\mu$. Another manifestation of the basic problem is that contrary to the fundamental spirit of rational expectations, $P(t)$ does not react to perfectly foreseen changes in the rate of monetary expansion until the change actually occurs. In particular, suppose that $z(s)=m(s)-k(s)$ is constant up to some time T, and then grows as a constant rate $Dz=\mu$ for $s>T$. According to (4), the path of $P(t)$ up to T is independent of the value of μ for $t>T$. Finally, note that as the speed of adjustment to disequilibrium α becomes large, the parameter γ that determines the stability of (4) tends to minus infinity. Thus, according to (4), when α is large, the rational path for the price level is necessarily unstable.

An alternative approach to finding a price adjustment rule that combines rational expectations with disequilibrium adjustment is to start with the standard rational expectations model and introduce sticky prices. The standard rational expectations models (see Thomas Sargent and Neil Wallace, 1973a) employ Cagan's assumption that the price level is determined by the condition of money market equilibrium:

$$P=m-k+\eta\cdot\Pi.$$

Imposing the requirement that $\Pi=DP$, it follows that

$$(5)\qquad DP=-(1/\eta)\cdot(z-P).$$

For this differential equation, we want the "forward looking solution" which is given by

$$(6)\quad P(t)=q(t)+(P(0)-q(0))\cdot exp((1/\eta)\cdot t),$$

where

$$(7)\quad q(t)\equiv\int_t^\infty(1/\eta)\cdot z(s)\cdot exp((-1/\eta)(s-t))ds.$$

If the initial price level $P(0)$ equals $q(0)$, the second term in (6) disappears, and $P(t)=q(t)$ for all t. In a model that assumes instanta-

be assumed that desired expenditure depends on the interest rate and that the interest rate adjusts instantaneously to clear the asset market. In such a model, excess demand in the goods market is inversely related to m^d-m, and directly related to the $\bar{P}-P$.

neous adjustment of prices, Sargent and Wallace (1973b) argue that $P(0)$ is a freely determined variable and that it is appropriate to fix the value of $P(0)$ by imposing the requirement that $P(0)=q(0)$.[2] This requirement insures that there is a well-defined path for $P(t)$ and that the long-run behavior of $P(t)$ is determined by the long-run behavior of $z=m-k$. In a model that assumes sticky prices, however, $P(0)$ is not a freely determined variable. In general, $P(0)$ will not equal $q(0)$ and, hence, the behavior of $P(t)$ implied by (6) will usually be explosive, regardless of the behavior of $z(s)=m(s)-k(s)$. Thus, it is apparent that the assumption of sticky prices and disequilibrium adjustment cannot be satisfactorily introduced into (6).

II. A Micro-economic Rationale for a Price Adjustment Rule

To develop a price adjustment rule that circumvents the difficulties encountered in combining rational expectations with sticky prices and disequilibrium adjustment, it is useful to examine how prices would be set if there were an explicit reason why prices should not instantaneously adjust to their equilibrium levels. The essential assumption in this analysis is that there is a cost associated with changes in the price of an individual commodity. Given this cost, it is optimal to adjust individual prices only at discrete intervals and by finite amounts, and to permit disequilibrium during the intervals between price changes. The optimal frequency of price change balances the marginal gains from reducing the losses due to disequilibrium (by changing prices more often) with the marginal cost of changing prices more frequently.

Let p denote the *log* of the price of a particular commodity. For simplicity, assume that the cost of changing the price of this commodity is a constant, A, independent of the size and direction of the price change. Further, suppose that the equilibrium price of this commodity, $\bar{p}$, is the optimal price from the standpoint of the price setter and that divergences from equilibrium generate a flow of losses given by

$$B\cdot(p(t)-\bar{p}(t))^2$$

where B is a constant.[3] Suppose that $\bar{p}$ is changing at a rate $\bar{\pi}$. If f is the frequency of price changes, then $T=1/f$ is the length of the interval for which the price is held constant. The loss generated during this interval by divergences from equilibrium is

$$\int_0^T B\cdot[p(0)-\bar{p}(0)+\bar{\pi}\cdot t]^2 dt,$$

where $p(0)$ is the value of p set at the start of the interval. The value of $p(0)$ which minimizes this loss is

$$p(0)=\bar{p}+(T/2)\cdot\bar{\pi}.$$

Given this choice of $p(0)$ disequilibrium loss during the interval is

$$(B/12)\cdot\bar{\pi}^2\cdot T^3,=(B/12)\cdot\bar{\pi}^2/f^3,$$

and the average loss per unit of time is

$$l_1(f,\bar{\pi})=(B/12)\cdot\bar{\pi}^2/f^2.$$

An increase in the frequency of price changes reduces this loss but increases the average

[2]The condition $P(0)=q(0)$ is not implied by the assumption that $DP=\Pi$. For this reason, F. Black (1972; 1974) argues that the path of the price level under rational expectations is not unique; there is a rational path of $P(t)$ for each choice of $P(0)$. If $P(0)$ is freely determined, however, there is nothing to preclude the assumption that $P(0)=q(0)$.

[3]The "equilibrium price" is the price that reflects both the play of market forces and the relative strength and skill of bargainers in any price negotiation. It is assumed that the objective of the price setting process is to set a price that is as close as possible (on average) to this equilibrium price. For the case of a monopolist facing a linear demand curve with additive shifts, Robert Barro (1972a) shows that the loss from a price that diverges from the profit maximizing price is proportional to the square of the divergence. More generally, the assumption that losses from divergences from equilibrium are proportional to the square of the divergence may be justified as an approximation, using a Taylor-series expansion of the objective of the price setter around the equilibrium price.

cost, per unit time, from price changes, $l_2(f) = A \cdot f$. The optimal frequency of price changes minimizes the total loss, $l_1 + l_2$; specifically,

$$(8) \qquad f^* = \left[(1/6)\cdot(B/A)\cdot\bar{\pi}^2\right]^{(1/3)}.$$

To analyze the behavior of the general price level, assume that the index of individual commodities, i, ranges over the interval $[0, 1]$, with the importance of individual commodities accounted for by the fraction of the interval assigned to that commodity so that in equilibrium all commodities have the same price. The *log* of the general price level, $P(t)$, is defined by

$$P(t) = \int_0^1 p(t; i)\,di.$$

To derive the rule of the adjustment of P, it is necessary to introduce assumptions concerning the frequency and timing of individual price changes and the relationship between the individual $\bar{\pi}$'s and the aggregate $\bar{\Pi}$. The simplest set of assumptions is that all commodities have the same frequency of price change f, that price adjustments are evenly spaced, and that the rates of change of the equilibrium prices of all commodities are all the same. The individual commodity prices in force at time t will be those prices which were established during the interval from $t-T$ to t, where $T = 1/f$. If i is the commodity whose price was fixed at time $t-s$, $0 \leq s \leq T$, then $p(t; i) = \bar{P}(t-s) + (T/2)\cdot\bar{\Pi}(t-s)$.

Ordering commodities by the date at which their price was last changed, it follows that

$$(9) \qquad P(t) = (1/T)\cdot\int_{t-T}^{t} \bar{P}(u) + (T/2)\cdot\bar{\Pi}(u)\,du.$$

Differentiation of (9) with respect to t yields

$$(10) \quad DP(t) = (1/T)\cdot\left[\bar{P}(t) + (T/2)\cdot\bar{\Pi}(t) - \bar{P}(t-T) - (T/2)\cdot\bar{\Pi}(t-T)\right]$$

$$= (2/T)\cdot\left[\bar{P}(t) - (1/2)\cdot\left(\bar{P}(t) + (T/2)\cdot\bar{\Pi}(t) + \bar{P}(t-T) + (T/2)\cdot\bar{\Pi}(t-T)\right)\right] + \bar{\Pi}(t).$$

Provided that $\bar{P}(u) + (T/2)\cdot\bar{\Pi}(u)$ is close to a linear function of u, $P(t)$ may be approximated by

$$P(t) \cong (1/2)\cdot\left[\bar{P}(t) + (T/2)\cdot\bar{\Pi}(t) + \bar{P}(t-T) + (T/2)\cdot\bar{\Pi}(t-T)\right].$$

Substitution of this approximation into (10) yields the price adjustment rule that characterizes the behavior of the general price level:

$$(11) \quad DP(t) = \bar{\Pi}(t) + \delta\cdot\left(\bar{P}(t) - P(t)\right)$$

where $\delta = 2/T$.

From this result, it is apparent that there is an important qualitative difference between adjustments of individual prices and adjustments of the general price level. Individual prices are held constant over a finite interval and then adjusted by discrete amounts to their expected (average) equilibrium levels for the subsequent interval. In contrast, the general price level moves continuously and adjusts gradually toward its equilibrium level. This behavior of the general price level reflects the fact that it is an average of the prices of individual commodities which are adjusted at different points of time.

The first term in the adjustment rule for the general price level, $\bar{\Pi}(t)$, is the (expected) rate of change of the *equilibrium* price level.[4]

[4]In a stochastic version of the present model, it may be shown that the proper term to include in the adjustment rule for the general price level is the *expected* rate of change of the equilibrium price level. In such a model, disequilibrium is generated by new information that leads to divergences between the actual and the expected rate of change of the equilibrium price level. Specifically, in a discrete time, stochastic version of the present model, it may be shown that the existing state of aggregate disequilibrium, $\bar{P}(t) - P(t)$, is a weighted average of past unexpected changes in the equilibrium price level, with exponentially declining weights.

The term keeps the price level from diverging further from its equilibrium level. The second term, $\delta\cdot(\bar{P}-P)$, drives the price level toward equilibrium if it is not already there. The average lag in reaching equilibrium is $1/\delta=T/2$; that is, the average lag is equal to the time it takes for the prices of one half of the individual commodities to adjust to their equilibrium levels. This average lag depends on the speed of convergence, δ, which reflects the economic factors influencing the frequency of adjustment of individual prices; specifically,

$$(12)\qquad \delta=\left[(4/3)\cdot(B/A)\bar{\Pi}^2\right]^{(1/3)}.$$

The derivation of the price adjustment rule (11) utilized special assumptions concerning the timing and frequency of individual price changes and the relationship between the behavior of the equilibrium prices of individual commodities and the aggregate equilibrium price level. Modifications of these assumptions lead to modifications in the precise forms of (11) and (12). In particular, if individual price adjustments are not evenly spaced, then the rate of change of the general price level will reflect the varying density of the individual price changes. More generally, if price setters adopt a strategy of changing prices when the divergence from equilibrium becomes "too large," then there will tend to be a bunching of individual price changes and a rather large adjustment of the general price level whenever some event simultaneously pushes disequilibrium in many individual markets beyond tolerable limits.[5]

These possible complexities, however, do not destroy the basic argument that justifies the general form of the two-part price adjustment rule given in (11), provided that three fundamental conditions remain satisfied. First, there must be a cost to changing an individual price. If there were no such cost, there would be no reason for prices ever to diverge from their equilibrium levels. Second, there must be a loss from allowing prices to diverge from their equilibrium levels, and this loss should be an increasing function of the magnitude of the divergence. This loss provides the incentive for the adjustment of individual prices. Third, price setters should recognize that the prices they set will prevail for a finite period and hence set prices which, on average, will be close to equilibrium during the period for which they are expected to prevail. To achieve this result, price setters will adjust prices both to correct for existing disequilibrium, and to account for roughly half of the expected change in the equilibrium price over the period for which the new price is expected to prevail. The correction for existing disequilibrium gives rise to the term $\delta\cdot(\bar{P}(t)-P(t))$ in (11), where the speed of adjustment δ is equal approximately to the inverse of half of the average period for which individual prices are held fixed. The term $\Pi(t)$ in (11) reflects the effect on price setting behavior of anticipated future changes in the equilibrium price level.

At the aggregate level, the price adjustment rule (11) is similar to the "expectations augmented Phillips curve" that has been widely employed in discussions of wage and price dynamics.[6] The major difference is that the present analysis indicates that the expected rate of change of the *equilibrium* price level $\bar{\Pi}$, rather than the expected rate of change of the actual price level Π, belongs in the price adjustment rule. This distinction is especially important when expectations are assumed to be rationale, for if the price adjustment rule were written as $DP=\Pi+\delta\cdot(\bar{P}-P)$ and it is assumed that $\Pi=DP$, we would obtain the clearly nonsensical result that $DP=DP+\delta\cdot(\bar{P}-P)$. The way around this difficulty is to recognize that the ap-

[5]The present model of the frequency of individual price adjustments assumes that the interval between price changes is fixed in advance. Analytically, this model is similar to the Tobin-Baumol model of the transactions demand for cash. An alternative model of the frequency of price adjustment could be based on the Miller-Orr model of the transactions demand for cash, and would allow price setters to follow a strategy of changing price when the divergence form equilibrium becomes sufficiently large to justify the cost of making the change.

[6]Several theoretical justifications for the expectations augmented Phillips curve are provided in Edmund S. Phelps et al. An excellent survey of the literature on this subject is provided in David Laidler and Michael Parkin.

propriate acceleration factor to include in the aggregate price adjustment rule, as implied by the present micro-economic analysis, is the expected rate of change of the equilibrium price level, $\overline{\Pi}$. Under the assumption of rational expectations, this leads to the sensible result that $DP = D\overline{P} + \delta \cdot (\overline{P} - P)$.

At the micro-economic level, there is also an important difference between the present rational for the rule $DP = \overline{\Pi} + \delta \cdot (\overline{P} - P)$ and the search theory rationale that is frequently given for the expectations augmented Phillips curve. In search theory models of price and wage dynamics, there is no "lumpiness" to individual price and wage adjustments. Rather, individual prices and wages adjust slowly over time as firms and workers acquire information, through time consuming search, about changes in equilibrium prices and wage rates. It is this slowness of individual price and wage adjustments, rather than the temporal aggregation of lumpy individual adjustments, that yields the stickiness in the adjustment of the general levels of prices and wages.

There is, however, no essential conflict between the search theory rationale for the expectations augmented Phillips curve and the present rationale for the price adjustment rule (11) based on costly and lumpy individual price changes. Both imply adjustment rules in which the current rate of price or wage change responds with a unitary coefficient to the expected rate of change of the equilibrium price or wage level, and in which there is gradual convergence of the actual price or wage rate to its equilibrium level. In general, the speed of convergence should reflect both the delay caused by the stickiness of individual prices and wage rates and the time required for economic agents to secure information about the behavior of the equilibrium levels of prices and wages.

III. Stability Properties of the Price Adjustment Rule

It is easily established that the price adjustment rule (11) resolves the theoretical difficulties of combining sticky prices and disequilibrium adjustment with the assumption of rational expectations. Under conditions of certainty, rational expectations require that the expected inflation rate $\Pi(t)$ correspond to the actual inflation rate $DP(t)$, and that the expected rate of change of the equilibrium price level $\overline{\Pi}(t)$ correspond to the actual rate of change of the equilibrium price level $D\overline{P}(t)$. These conditions, together with the price adjustment rule (11) and the definition of the equilibrium price level, $\overline{P} = m - k + \eta \cdot \Pi = z + \eta \cdot \Pi$, imply that $P(t)$ must satisfy the second-order differential equation:[7]

$$(13) \quad DP = \overline{\Pi} + \delta(\overline{P} - P) = (Dz + \eta D^2 P) + \delta \cdot (z + \eta DP - P),$$

where D^2P is the second derivative of P with respect to time.

This differential equation has two characteristic roots, $1/\eta$ and $-\delta$, and a general solution that is given by

$$(14) \quad P(t) = U \cdot exp((1/\eta) \cdot t) + V \cdot exp(-\delta t) + q(t),$$

where, as in (7),

$$(15) \quad q(t) = (1/\eta) \cdot \int_t^{\infty} z(s) \cdot exp(-(1/\eta)(s-t))\, ds.$$

A specific solution for $P(t)$ is determined by imposing initial and terminal conditions that fix the values of the coefficients U and V. An initial condition is implied by the assumption of sticky prices; specifically, since $P(0)$ is fixed by the conditions prevailing before $t = 0$, we require that

$$(16) \quad U + V = P(0) - q(0).$$

[7]This discussion ignores the nonlinearity induced by the fact that δ depends on $\overline{\Pi}$. This does not affect the basic point that the form of the price adjustment rule must allow for a sensible two-part solution for the price level. One part, which represents the equilibrium price level, must be a stable, forward-looking function of the future path of $m - k$. The other part, which reflects the effect of the disequilibrium inherited at time 0, should decline with the passage of time.

A terminal condition is implied by the requirement that $P(t)$ should not explode to plus or minus infinity unless driven to do so by the behavior of z.[8] For this sensible requirement to be satisfied, we must impose (7)

$$U=0. \tag{17}$$

From (14), (16), and (17), we obtain a unique solution for $P(t)$:

$$P(t)=q(t)+(P(0)-q(o))\cdot exp(-\delta\cdot t). \tag{18}$$

In this solution, $q(t)$ represents the full equilibrium price level; that is, $q(t)$ determines the path $P(t)$ would follow if there were no disequilibrium. The initial divergence between the price level and its full equilibrium value is determined by the difference between $P(0)$ and $q(0)$. From (18) it is apparent that the divergence between $P(t)$ and $q(t)$ disappears at an exponential rate δ, and that in the long run, the price level converges to its full equilibrium value. Thus, a high speed of response of prices to disequilibrium creates no problem for the stability of the price adjustment process. Quite the contrary, the greater the response coefficient δ, the more rapidly the price level converges to its full equilibrium path.

It is important to note the essential mathematical properties of the price adjustment rule that are responsible for this strong stability result; specifically, the combination of the price adjustment (11) with the assumption of rational expectations results in a second-order differential equation for $P(t)$ which has one positive and one negative characteristic root. The positive characteristic root is required because rational expectations look forward in time. Specifically, expectations of future values of $m-k$ influence $P(t)$ through the forward-looking integral that defines $q(t)$. For this integral to converge, the differential equation determining $P(t)$ must have a positive characteristic root. The negative characteristic root is required because the process of adjustment to disequilibrium looks backward in time. For such a backward-looking process to be stable, the differential equation controlling $P(t)$ must have a negative characteristic root.

From a mathematical point of view, it is apparent that the price adjustment rule (11) possesses the requisite properties for a successful combination of rational expectations with sticky prices and disequilibrium adjustment. From an economic point of view, it is especially interesting that this form of price adjustment rule need not be justified solely on the basis of its desirable mathematical properties. It is also the form of price adjustment rule that is implied by sensible price setting behavior in circumstances where there is an economic reason for sticky prices and slow adjustment to disequilibrium.

[8]Because this terminal condition is not implied by the standard requirement of rational expectations that $\Pi=DP$, there has been considerable controversy over the justification for imposing it. The present analysis contributes nothing to the resolution of this controversy. It does make clear, however, that this controversial issue is separate and distinct from the problem of combining rational expectations with sticky prices and disequilibrium adjustment. Since there are two undetermined coefficients in (14), we can both satisfy the initial condition implied by the assumption of sticky prices and also impose the terminal condition that insures sensible long-run behavior of $P(t)$.

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The Private and Social Utility of Extortion

By JOHN A. C. CONYBEARE*

A recent exchange between George Daly and J. Fred Giertz and Harold Demsetz focused attention on the social efficiency of extortion. Daly and Giertz suggested that extortion could be defined as "... the act of obtaining payments from some entity in return for *not* imposing upon that entity some harmful effect, where the generator of the external effect receives no direct net internal benefit from the act" (p. 998). Extortion is, they say, an act which merely redistributes income and reduces social welfare by the amount of any transaction costs. It is thus distinguished from legitimate bargaining, which will produce social welfare gains. Demsetz replied to this argument by pointing out that there are many activities which might result in social welfare gains but are, nevertheless, prohibited as extortionary acts. The legality of a threat bears only a very rough relationship to the social utility of the act, and the definition of extortion is therefore "legalistic" rather than economic, according to Demsetz.

The difference between these two positions relates to the definition of the extortionary act itself. If *A* demands property from *B* under threat to accuse *B* of a crime, extortion has occurred. The act which is being threatened may have individual utility to *A* of equal to or less than zero, as Daly and Giertz correctly point out. There may also be a net gain in social utility either if the threat is of some value to society (for example, it may help deter crime) or if the property transferred is worth more to *A* than to *B* (for example, perhaps because of unequal marginal utilities). Thus, an economic interpretation of extortion must be more narrowly defined as the threat to commit an act which *by itself* would not materially benefit the actor *alone*. Daly and Giertz are correct in postulating the existence of an economic definition of extortion consistent with current legal practice, though wrong in their inferences about its direct social (rather than individual) utility. Demsetz correctly points out that individual acts of extortion may have positive social utility effects, but incorrectly concludes that any definition of extortion must therefore be legalistic. The following discussion indicates that legal theory is broadly consistent with an individual utility interpretation of extortion. It is only the delimitation of the benefits of the threatened extortionary act, not the definition of extortion, which is purely a legalistic question.

English criminal law, as embodied in the Larceny Act (1916), specified blackmail (used synonomously with the term extortion) as "... the demanding of any person with menaces, and without reasonable or probable cause, any property or valuable thing ..." (see J. W. C. Turner, p. 312). Such menaces include: threats to accuse another of a crime, unlawful violence or restraint, threats to publish and, in general, any threat that "... should produce in any ordinary man such a degree of fear or alarm as would unsettle his mind" (Turner, p. 315). The distinction sought in the act is whether there is a clear nexus between the act threatened and the property demanded, and whether there is value by itself in the act threatened, the degree of nexus being one criterion for judging the latter.

G. L. Williams' survey of English law on blackmail provides ample evidence of the legal pursuit of this distinction, particularly the emphasis on the private utility of the extortionary act itself. He refers to the Dymond case in 1920, which provided the modern English precedent. In this case, a girl who alleged that she had been indecently assaulted wrote to the man in question demanding money under threat of adverse publicity about his moral character. She was convicted of blackmail on the grounds that

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the threat to accuse another of an immoral act or to prosecute him for a crime is an unreasonable means of obtaining property. As Williams (pp. 165–66) points out, had the girl written to the man threatening civil damage proceedings, the question of blackmail would never have arisen. The general criterion which Williams draws from the English cases is that a legitimate threat is one where "... some material advantage would come to the accused [the defendant] through the carrying out of his threat" (Williams, p. 172). This definition of extortion, as a threat to perform an act which would not otherwise benefit the actor, is consistent with that proposed by Daly and Giertz.

The difficulty is, of course, in delimiting the private utility associated with the act threatened. Williams also cites a 1937 exclusive dealing case where a motor vehicle dealer brought blackmail action against a trade association which refused to supply him with vehicles after he had sold at less than list prices. The association offered him the option of a fine as an alternative to being put out of business. The dealer lost the case, the court taking the view that the trade association had a "lawful business interest" in making such a threat (Williams, pp. 171–72). A 1908 case of a gambling house that posted the name of a debtor was ruled to be not extortionary on the grounds that such an act is a legitimate means of securing payment of a debt of honor. In both cases the positive gain to the party making the threat was considered to be sufficiently closely connected to the act threatened, that the threat could not constitute extortion under the utility rule. If, on the other hand, the gambling house had threatened to inform the debtor's grandmother of the debt, or the trade association threatened to damage the trader's vehicles, such a threat would have constituted blackmail (see Williams, p. 169).

The supply of goods or services for money is considered to be naturally connected, such that the threat of refusal to supply goods or services (for example, in the case of monopoly) is not considered extortionary. Commenting on the case of the motor trade association cited above, Williams quotes Lord Wright's judgment on how closely connected a threat and benefit must be in order to constitute a "lawful business interest":

> [A man] may offer not to build on his plot of land if he is compensated for abstaining. He is entitled to bargain as a consideration for agreeing not to use his own land as he lawfully may, and the other man may think it worth while to pay him, rather than have the amenities of his house destroyed by an eyesore. Or a valued servant may threaten to go to other employment unless he is paid a bonus or increased wages. Or a man may offer to abstain from prosecuting for a common assault or infringement of his trade mark if he is paid compensation for the civil wrong. [p. 172]

Williams notes that "This means that what some people regard as the commonest form of blackmail in modern society—strikes for higher wages by persons whose work is essential to the community—is not a criminal offense" (p. 172).

The U.S. criminal law adopts a definition of extortion close to that established by English precedent. The U.S. Model Penal Code (section 223.4g) defines extortion as the acquiring of property by a threat to inflict "... harm which would not benefit the actor."

Thus, both Daly and Giertz, and Demsetz are partially correct. The act of extortion can be economically defined, in terms of individual private utility, as the threat to perform an action of no benefit to the actor. The question of how closely associated with the act potential benefits to the actor must be, in order for the threat not to be extortionary, provides the basis for much legal argument. There is a legalistic problem insofar as it may be difficult to distinguish between the act threatened and the benefit to the actor of associated effects.

This leaves open the question of why society should declare illegal individual acts of extortion where the social utility is greater than zero. Why should we not apply social utility criteria to extortion if, as Demsetz suggests, some extortionary acts may well have positive social utility? Why should we

not prohibit only those extortionary acts where net social utility is less than zero? Limiting the utility calculus to the individual making the threat can be justified on broader social utility grounds. The overall social benefit of most extortionary acts would be highly uncertain and difficult to evaluate. This applies both to the value of the threat (for example, the crime reducing effect of allowing people to accuse others of crimes) and to the possibility that the property transferred is worth more to the actor making the threat. These rationales for prohibiting all extortionary acts, rather than only those with negative social utility, are discussed at greater length by G. Calabressi and A. D. Melamed (p. 1125), who focus on the uncertainty of valuing the property transferred, and by R. A. Posner (p. 358), who puts forward a more general case for the relative efficiency of property rights in the area of criminal law.

It appears, therefore, that the Daly-Giertz and Demsetz debate on the social utility of extortion is not a fruitful one, depending merely upon the specification of which utilities are to be associated with the extortionary act itself. Narrowly defined, the threat to perform an act of no material value to the actor does appear to be supported by legal precedent as a criterion for extortion, though individual acts of extortion may involve net social gains. The economic definition of extortionary activities can be seen in social utility terms only in a wider context. Rather than attempting to define the utility of each criminal act itself, such a definition focuses on the efficiency of protecting many entitlements by property rights, not allowing them to be involuntarily converted into liability rules.

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On the Futility of Criticizing the Neoclassical Maximization Hypothesis

By LAWRENCE A. BOLAND*

The last few years have seen an intensification of methodological criticism of the foundations of neoclassical theory and in particular of the maximization hypothesis. Harvey Leibenstein argued for a "Micro-Micro Theory" on the grounds that profit maximization is not necessarily the objective of the actual decision makers in a firm and that a complete explanation would require an explanation of intrafirm behavior. He also gave arguments for why maximization of anything may not be realistic or is at best a special case. Herbert Simon's Nobel lecture argued that individuals do not actually maximize anything—they "satisfice." And of course, George Shackle has for many years argued that maximization is not even possible.

Some antineoclassical economists are very encouraged by these arguments, but I think these arguments are unsuccessful. For anyone opposed to neoclassical theory, a misdirected criticism which by its failure only adds apparent credibility to neoclassical theory will be worse than the absence of criticism. The purpose of this paper is to explain why, although the neoclassical hypothesis is *not* a tautology, no criticism of that hypothesis will ever be successful. My arguments will be based first on the possible types of theoretical criticism and the logic of those criticisms, and second on the methodological status of the maximization hypothesis in neoclassical explanations.

I. Types of Criticism and the Maximization Hypothesis

There are only two types of criticism of any behavioral hypothesis once one has established its logical validity. One can argue against the *possibility* of the hypothesized behavior or one can argue against the empirical truth of the premise of the hypothesis. In the case of the neoclassical maximization hypothesis, virtually everyone accepts the logical validity of the hypothesis. For example, everyone can accept that *if* the consumer is a utility maximizer, then for the particular bundle of goods chosen: (a) the marginal utility is zero, and (b) the slope of the marginal utility curve at the point representing the chosen bundle is nonpositive and usually negative.[1] That is to say, necessarily the marginal increment to the objective must be zero and falling (or not rising) whenever (i.e., without exception) the maximization premise is actually true. Of course, one could substitute the word "profit" for the word "utility" and the logic of the hypothesis still holds. In either form (a) and (b) are the "necessary conditions" for maximization. Note that there are no "sufficient conditions" for maximization. Rather, the maximization premise is the sufficient condition for (a) and (b).

Parenthetically, I should note that economists often refer to (b), or more properly to the conjunction of (a) and (b), as a sufficient condition for maximization. This is a common error. Even if (a) and (b) are both true, only *local* maximization is assured. However, maximization in general (i.e., *global*) is what the premise explicitly asserts and that is not assured by (a) and (b) alone. I will return to this in Section III when I discuss the methodological uses of the maximization hypothesis.

II. The Logical Basis for Criticism

As stated above, there are two types of criticism of the maximization hypothesis: the

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[1]Note that any hypothesized utility function may already have the effects of constraints built in as is the case with the Lagrange multiplier technique.

possibilities criticism and the *empirical* criticism. In this section I will examine the logical bases of these critiques, namely of the possibilities argument which concerns only the *necessary conditions* and of the empirical argument which concerns only the *sufficient conditions*. In each case I will also discuss the possible logical defense for these criticisms.

A. *The Possibilites Critique: Can the Necessary Conditions be Fulfilled?*

The possibilities critique builds on the difference between necessary and sufficient conditions. Specifically, what is criticized is the possibility of fulfilling *all* of the necessary conditions for maximization. Of course, this type of critique begs the question as to what are all the necessary conditions. Are there more conditions than the (a) and (b) listed above? Shackle, following Friedrich Hayek and John Maynard Keynes, argues that maximization also presumes that the knowledge necessary for the process of choosing the "best" alternative has been acquired.[2] That is to say, as a behavioral hypothesis (i.e., about the behavior of decision makers) if maximization is a deliberate act, Shackle argues that the actor must have acquired all of the information necessary to determine or calculate which alternative maximizes utility (or profit, etc.) and he argues that such acquisition is impossible hence deliberate maximization is an impossible act.

This argument appears to be quite strong although it is rather elementary. A closer examination will show it to be overly optimistic because it is epistemologically presumptive. One needs to ask: *Why* is the possession of the necessary knowledge impossible? This question clearly involves one's epistemology — that is, one's theory of knowledge. The answer, I think, is quite simple. Shackle's argument (also Hayek's and Keynes') presumes that the truth of one's knowledge requires an inductive proof (see my 1978 paper). And as everyone knows today, there is no inductive logic which could supply a proof whenever the amount of information is finite or it is otherwise incomplete (for example, about the future).

The strength of the Shackle-Hayek-Keynes argument is actually rather vulnerable. Inductive proofs (and hence inductive logic) are not necessary for true knowledge. One's knowledge (i.e., one's theory) can be true even though one does not know it to be true—that is, even if one does not have proof. But I think there is an even stronger objection to the "true knowledge is necessary for maximization" argument. *True* knowledge is not necessary for maximization! As I have argued elsewhere, the consumer, for example, only has to think that his theory of what is the shape of his utility function is true. Once the consumer picks the "best" option there is no reason to deviate or engage in "disequilibrium behavior" unless he is prone to testing his own theories.[3]

In summary, the Shackle-Hayek-Keynes inductivist argument against the possibility of a true maximization hypothesis is a failure. Inductive proofs are not necessary for true knowledge and true knowledge (by any means) is not necessary for successful or determinate decision making. Maximization behavior cannot be ruled out as a logical impossibility.

B. *The Empirical Critiques: Is the Sufficient Premise True?*

Simon and Leibenstein argue against the maximization hypothesis in a more straightforward way. While accepting the logical validity of the hypothesis, they simply deny the truth of the premise of the hypothesis. They would allow that *if* the consumer is actually a maximizer, the hypothesis would be a true explanation of the consumer's behavior but they say the premise is false;

[2]Although the Shackle-Hayek-Keynes argument applies to the assumption of either local or global maximization, it is most telling in the case of global maximization.

[3]Again this raises the question of the intended meaning of the maximization premise. If global maximization is the intended meaning, then the consumer must have a (theory of his) preference ordering over all conceivable alternative bundles. At a very minimum, he must be able to distinguish between local maxima all of which satisfy both necessary conditions, (a) and (b).

consumers are not necessarily maximizers hence their behavior (for example, their demand) would not necessarily be determinable on that basis. Leibenstein may allow that the consumer's behavior can be determined, but it is an open question as to what is the determining factor—utility, prestige, social convention, etc.? Simon seems to reject as well the necessity of determinate explanation although he does discuss alternate decision rules to substitute for the maximization rule.[4]

A denial of the maximization hypothesis on empirical grounds raises the obvious question: How do they know the premise is false? Certain methodological considerations would seem to give an advantage to the critics over those who argue in its favor. Recall that we distinguish between those statements which are verifiable (i.e., can be proven true) and those which are refutable (i.e., can be proven false) on purely logical grounds. As we know, (strictly) universal statements—those of the form "*all X*'s have property *Y*"—are refutable (if false) but not verifiable (even if true). On the other hand, (strictly) existential statements—those of the form "there are *some X*'s which have property *Y*"—are verifiable (if true) but not refutable (even if false). At first glance it would seem that the maximization hypothesis —"all decision makers are maximizers"—is straightforwardly a universal statement and hence is refutable but not verifiable. But the statistical problems of empirical refutation present many difficulties. Some of them are well known, but as I shall show a little later, the logical problems are insurmountable.

The methodological problems of empirical refutations of economic theories are widely accepted. In the case of utility maximization we realize that survey reports are suspect and direct observations of the decision-making process are difficult or impossible. In this sense behavioral maximization is not directly testable. The only objective part of the maximization hypothesis is the set of logical consequences such as the uniquely determinate choices. One might thus attempt an indirect test of maximization by examining the outcomes of maximization, namely, the implied pattern of observable choices based on a presumption that there is a utility function and that utility is being maximized by the choices made.

If one wishes to avoid errors in logic, an indirect test of any behavioral hypothesis which is based on a direct examination of its logical consequences must be limited to attempting refutations of one or more of the necessary conditions for the truth of the hypothesis. For example, in the case of consumer theory, whenever utility maximization is the basis of observed choices, a necessary condition is that for any given pattern of choices the "Slutsky Theorem" must hold (see William Baumol, pp. 336–39). It might appear then that the above methodological problems of observation could be easily overcome, since the Slutsky Theorem can in principle be made to involve only observable quantities and prices. And, if one could refute the Slutsky Theorem then one could indirectly refute the maximization hypothesis.[5] Unfortunately, even if from this perspective such an indirect refutation cannot be ruled out on logical grounds alone, the methodological problems concerning observations will remain.

The fundamental methodological problem of refuting any behavioral hypothesis indirectly is that of constructing a convincing refutation. Any indirect test of the utility maximization hypothesis will be futile if it is to be based on a test of any logically derived implication (such as the Slutsky Theorem). On the one hand, everyone—even critics of maximization—will accept the theorem's logical validity. On the other hand, given the numerous constraints involved in any concrete situation, the problems of observation

[4]Some people have interpreted Simon's view to be saying that the reason why decision makers merely satisfice is that it would be "too costly" to collect all the necessary information to determine the unique maximum. But this interpretation is inconsistent if it is a justification of assuming only "satisficing" as it would imply cost minimization which of course is just the dual of utility maximization!

[5]For example, if one could show that when the income effect is positive but the demand curve is positively sloped, then the Slutsky Theorem would be false or there is no utility maximization (see Cliff Lloyd).

will be far more complex than those outlined by the standard theory. Thus, it is not difficult to see that there are numerous obstacles in the way of constructing any convincing refutation of maximization, one which would be beyond question.

I now wish to offer some new considerations about the potential refutations of the neoclassical behavioral hypothesis. I will argue here that even if one could prove that a consumer is not maximizing utility or a producer is not maximizing profit, this would not constitute a refutation of the neoclassical hypothesis. The reason why is that the actual form of the neoclassical premise is not a strictly universal statement. Properly stated, the neoclassical premise is: "For all decision makers there is something they maximize." This statement has the form which is called an "All-and-some statement." All-and-some statements are neither verifiable nor refutable! As a universal statement claiming to be true for all decision makers, it is unverifiable. But, although it is a universal statement and it should be logically possible to prove it is false when it is false (viz., by providing a counterexample) this form of universal statement cannot be so easily rejected. Any alleged counterexample is unverifiable *even if the counterexample is true*!

Let me be specific. Given the premise—"All consumers maximize something"—the critic can claim he has found a consumer who is not maximizing anything. The person who assumed the premise is true can respond: "You claim you have found a consumer who is not a maximizer but how do you know there is not something which he is maximizing?" In other words, the verification of the counterexample requires the refutation of a strictly existential statement; and as stated above, we all agree that one cannot refute existential statements.

In summary, empirical arguments such as Simon's or Leibenstein's that deny the truth of the maximization hypothesis are no more testable than the hypothesis itself. Note well, the logical impossibility of proving or disproving the truth of any statement does not indicate anything about the truth of that statement. The neoclassical assumption of universal maximization could very well be false, but as a matter of logic we cannot expect ever to be able to prove that it is.

III. The Importance of Distinguishing between Tautologies and Metaphysics

Some economists have charged that the maximization hypothesis should be rejected because, they argue, since the hypothesis is not testable it must then be a tautology hence it is "meaningless" or "unscientific." Although they may be correct about its testability, they are wrong about its being necessarily a tautology. Statements which are untestable are not necessarily tautologies because they may merely be metaphysical.

A. *Distinguishing between Tautologies and Metaphysics*

Tautologies are statements which are true by virtue of their logical form alone—that is, one cannot even conceive of how they could ever be false. For example, the statement "I am here or I am not here" is true regardless of the meaning of the nonlogical words "I" or "here." There is no conceivable counterexample for this tautological statement. But, the maximization hypothesis is not a tautology. It is conceivably false. Its truth or falsity is not a matter of logical form. The problem with the hypothesis is that it is metaphysical.

A statement which is a tautology is intrinsically a tautology. One cannot make it a nontautology merely by being careful about how it is being used. A statement which is metaphysical is *not* intrinsically metaphysical. Its metaphysical status is a result of *how* it is used in a research program. Metaphysical statements can be false but we may never know because they are the assumptions of a research program which are *deliberately put beyond question*. Of course, a metaphysical assumption may be a tautology but that is not a necessity.

Typically, a metaphysical statement has the form of an existential statement (for example, there is class conflict; there is a price system; there is an invisible hand; there will be a revolution; etc.). It would be an error to think that because a metaphysical existential

statement is irrefutable that it must also be a tautology. More importantly, a unanimous acceptance of the truth of any existential statement still does not mean it is a tautology.

Some theorists inadvertently create tautologies with their *ad hoc* attempts to overcome any possible informational incompleteness of their theories. For example, as an explanation, global maximization implies the adequacy of the consumer's preferences or his theory of all conceivable bundles which in turn implies his acceptance of an unverifiable universal statement. Some theorists thus find global maximization uncomfortable as it expects too much of any decision maker—but the usual reaction only makes matters worse. The maximization hypothesis is easily transformed into a tautology by limiting the premise to local maximization. Specifically, while the necessary conditions (a) and (b) are not sufficient for global maximization, they are sufficient for local maximization. If one then changes the premise to say, "if the consumer is maximizing over the neighborhood of the chosen bundle," one is only begging the question as to how the neighborhood was chosen. If the neighborhood is defined as that domain over which the rate of change of the slope of the marginal utility curve is monotonically increasing or decreasing, then at best the hypothesis is circular. But what is more important here, if one limits the premise to local maximization, one would severely limit the explanatory power or generality of the allegedly explained behavior.[6] One would be better off maintaining one's metaphysics rather than creating tautologies to seal their defense.

B. *Metaphysics vs. Methodology*

Fifty years ago metaphysics was considered a dirty word but today most people realize that every explanation has its metaphysics. Every model or theory is merely another attempted test of the "robustness" of a given metaphysics. Every research program has a foundation of given behavioral or structural assumptions. Those assumptions are implicitly ranked according to their questionability. The last assumptions on such a rank-ordered list are the metaphysics of that research program. They can even be used to define that research program. In the case of neoclassical economics, the maximization hypothesis plays this methodological role. Maximization is considered fundamental to everything; even an assumed equilibrium need not actually be put beyond question as disequilibrium in a market is merely a consequence of the failure of all decision makers to maximize. Thus, those economists who put maximization beyond question cannot "see" any disequilibria (for example, the Coase theorem).

The research program of neoclassical economics is the challenge of finding a neoclassical explanation for any given phenomenon—that is, whether it is possible to show that the phenomenon can be seen as a logical consequence of maximizing behavior—thus, maximization is beyond question for the purpose of accepting the challenge.[7] The only question of substance is whether a theorist is willing to say what it would take to convince him or her that the metaphysics used failed the test. For the reasons I have given in Section II, no logical criticism of maximization can ever convince a neoclassical theorist that there is something intrinsically wrong with the maximization hypothesis.

Whether maximization should be part of anyone's metaphysics is a methodological problem. Since maximization is part of the metaphysics, neoclassical theorists too often employ *ad hoc* methodology in order to deflect possible criticism; thus any criticism or defense of neoclassical maximization must

[6]See fn. 3 above. If one interprets maximization to mean only local maximization, then the question is begged as to how a consumer has chosen between competing local maxima.

[7]For these reasons the maximization hypothesis might be called the "paradigm" according to Thomas Kuhn's view of science. But note that the existence of a paradigm or of a metaphysical statement in any research program is not a psychological quirk of the researcher. Metaphysical statements are necessary because we cannot simultaneously explain everything. There must be some exogenous variables or some assumptions (for example, universal statements) in every explanation whether it is scientific or not.

deal with neoclassical methodology rather than the truth of the assumption. Specifically, when criticizing any given assumption of maximization it would seem that critics need only be careful to determine whether or not the truth of the assumption matters. It is true that for followers of Friedman's instrumentalism, the truth of the assumption does not matter hence for strictly methodological reasons it is futile to criticize maximization. And the reasons are quite simple. Practical success does not require true knowledge and instrumentalism presumes that the sole objective of research in economic theory is immediate solutions to practical problems. The truth of assumptions supposedly matters to those economists who reject Friedman's instrumentalism, but for those economists interested in developing economic theory for its own sake, I have argued here that it is still futile to criticize the maximization hypothesis. There is nothing intrinsically wrong with the maximization hypothesis. The only problem, if there is a problem, resides in the methodological attitude of most neoclassical economists.

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Cross-Section Tests of the Heckscher-Ohlin Theorem: Comment

By JAMES E. ANDERSON*

In a recent issue of this *Review*, Jon Harkness proposed a novel Ohlin-like regression hypothesis relating commodity trade to factor requirements in the case of many goods and factors. This comment will argue that Harkness' hypothesis is implausible in the light of the other restrictions on the trade model. If, however, it is accepted as an unidentified but stable relationship, the trade model produces restrictions on the coefficients of the linear regression relationship. Harkness proposed a further ranking condition which cannot hold in general (as he noted).

I. Harkness' Hypothesis

Suppose there are n goods and m primary factors, with $n \geqslant m$. Intermediate factors are suppressed by dealing with vertically integrated final good sectors. Choose units at equilibrium such that all commodity and factor prices are unity. Let θ be the factors shares matrix, $n \times m$, with the shares for industry i along the ith row. Let E be the commodity trade vector (in value and quantity terms), with positive values for exports and negative values for imports. Embodied factor trade is given by (in value and quantity terms):

$$F = \theta' E. \tag{1}$$

Positive elements of F are embodied net exports and negative elements are embodied net imports.

The Travis-Vanek generalization[1] of the Heckscher-Ohlin theorem states that the elements of F divided by the corresponding elements of the national factor endowment vector will have the opposite ranking to the elements of the "rest of the the world" factor endowment divided by the corresponding elements of the national factor endowment vector. That is, import (export) factors in which the rest of the world is relatively abundant (scarce).

The Travis-Vanek theorem permits no identification of commodity trade save in special cases (like $n=m=2$ case of the original Heckscher-Ohlin theorem). It says that the fundamental logic of the Heckscher-Ohlin model concerns factor movements and the proposition that commodity trade can be a perfect substitute. As an attempt to rescue a commodity trade proposition, Harkness proposes a regression relationship which will permit identification of commodity trade by knowing factor requirements. Let Y be the output vector and let *diag* Y be a diagonal $n \times n$ matrix with the elements of Y on the diagonal. Harkness' hypothesis is

$$(diag\ Y)^{-1} E = \theta\beta + \varepsilon. \tag{2}$$

ε is a classical zero-mean spherical disturbance term. The coefficient vector β, $m \times 1$, gives weights to be applied to factor shares to determine, going across commodities, whether good i is an import or an export. Harkness hypothesizes further that β should follow the Travis-Venek rank order. That is, let G be the national factor endowment vector, and *diag* G the $m \times m$ diagonal matrix with the elements of G strung along the diagonal. Then Harkness proposes that the rank correlation between $(diag\ G)^{-1}F$ and β should be perfect.

Equation (2) can be estimated by ordinary least square methods, and Harkness has done so with U.S. data. He gets a very nice fit on equation (2) and a reasonably high rank correlation between $(diag\ G)^{-1}F$ and β (a

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[1]See William Travis and Jaroslav Vanek. Harkness (and others) give Travis no credit, but on pp. 102–03 he has the essential algebra.

range from .72 to .65). He reports a significance test on the null hypothesis that the rank correlation coefficient is zero. The proper null hypothesis is that rank correlation is perfect. Using the normal approximation to the distribution of the rank correlation coefficient yields a standard error of .235. Harkness' ranking hypothesis thus fails to be rejected at the 95 percent level of confidence, but with point estimates falling between 1.2 and 1.5 standard deviations below unity, this is weak confirmation.

II. A Critique

Harkness offers no theoretical justification for (2). We shall argue it is implausible in light of the other requirements of the trade model. Assume first that $n=m$. Assuming θ has full column rank, we may invert in (1) and obtain

$$E=(\theta')^{-1}F. \tag{3}$$

Now scale the variables as in Harkness (2):

$$\begin{aligned}(4)\quad & (diag\ Y)^{-1}E \\ &=(diag\ Y)^{-1}(\theta')^{-1}(diag\ G)(diag\ G)^{-1}F \\ &=\left[(diag\ G)^{-1}\theta'(diag\ Y)\right]^{-1}(diag\ G)^{-1}F \\ &=\lambda^{-1}(diag\ G)^{-1}F\end{aligned}$$

λ is the matrix of proportionate factor allocations with the share of total endowment of factor j to industry i being the jth row and ith column entry. If (4) were regarded as a statistical relationship, it would state that proportionate commodity trade, $(diag\ Y)^{-1}E$, is perfectly explained by a linear combination of the columns of λ^{-1}. Furthermore, the coefficient vector of the linear relationship would *equal* (not just have the ranking of) the proportionate factor trade vector, $(diag\ G)^{-1}F$.

If there is a natural relationship between proportional commodity trade and the factor requirements matrix it is through the inverse. In the Travis-Vanek version of the Heckscher-Ohlin model, with identical homothetic utility functions across countries, $(diag\ G)^{-1}F=(1-\alpha)\iota-\alpha(diag\ G)^{-1}G^*$, where α = the ratio of home national income to world income, G^* is the rest of the world's endowment vector, and ι is the vector of ones. Equation (4) should thus be a reasonably stable relationship (in this context, in the contrived sense of stable across repeated sampling). Given that, why should (2) be stable? Stability of both (4) and (2) requires restrictions on admissible changes in θ and/or ε, the "disturbance" term. These restrictions have no obvious appeal.

Now consider the case of $n>m$. Equation (1) no longer gives a unique invertible relationship. There are infinitely many generalized inverses which would be analogous to the "data" matrix in (4). There is thus no stable function of elements of the factor requirements matrix which yields the commodity trade vector. To the extent that it is useful a priori to think about such a relation, however, it is again through an inverse. As in the square $n=m$ case, why should (2) be stable?

On the other hand, Harkness gets a good fit with (2). Accepting it as an unidentified but useful relationship, there is no reason to limit the regressors to the factor shares vectors. Equation (2) is written as a homogeneous function but Harkness estimates it with a constant term due to omitted factors of production. Harkness suggests (p. 794) that his constant term may also represent the influence of such variables as tariff and nontariff barriers, scale economies, and noncompetitive market structure. Implicitly, his slope terms are not so influenced, since he uses them to test the rank hypothesis without further comment. This is clearly false. Suppose first that (2) is the true model. Since the theoretical θ matrix has unit row sums, his procedure is identical to estimating a homogenous form with an added regressor equal to the share of omitted factors: the coefficient of the omitted factor share is equal to Harkness' constant term, and the true coefficients of the included factor shares equal the estimated slopes minus the estimated constant. The influence of alternative trade theories can be "tested" only by including additional regressors which act differentially across sectors. Now suppose such regressors

belong in the equation and Harkness omitted them. To the extent that they are not orthogonal to all the factor shares, their influence biases not only the constant term, but also the slope terms. No presumption about relative magnitude of bias is possible without more information.

Returning to the pure Ohlinian case Harkness estimates, what restrictions does the H-O model give for the relationship of β and $(diag\ G)^{-1}F$? Combining (1) and (2) we have:

$$(5) \quad \theta'(diag\ Y)\theta\beta+\theta'(diag\ Y)\varepsilon=F.$$

Scaling both sides by $(diag\ G)^{-1}$ we have

$$(6) \qquad \lambda\theta\beta+\lambda\varepsilon=(diag\ G)^{-1}F.$$

The least squares regression estimator of β in (2) is

$$(7) \qquad \hat{\beta}=(\theta'\theta)^{-1}\theta'(diag\ Y)^{-1}E.$$

Harkness' rank hypothesis (or even the sign hypothesis), as he points out, is more or less equivalent to assuming the cross correlations in $(\theta'\theta)^{-1}$ do not matter in (7). This is highly restrictive. For the general case we can go a little further. Equation (5) assures us that $\beta'F>0$ in the "population," since $\theta'(diag\ Y)\theta$ is positive definite. Thus "on average," β and F are positively associated. With $\iota'F=0$, a trade balance of zero, the measure of association is ordinary (not rank) correlation. (5) also provides a constraint on β. Multiplying both sides by ι', we obtain $G'\beta=\iota'F$, the β vector must weight the endowment vector to equal the trade balance.

Equation (6) appears to tell us that a "magnification effect" is the partial derivative link between relative embodied factor trade and the coefficient vector β. For changes in $(diag\ G)^{-1}F$ due to shifts in the foreign endowment vector at constant prices, this is correct. $\lambda\theta$ is a row stochastic matrix. Its inverse, since $(\lambda\theta)(\lambda\theta)^{-1}=I$, must have in each column at least one negative element and one element greater than one.[2] Thus if the foreign endowment shifts by dG^*, at constant prices there is a shift in relative embodied factor trade of $[-\iota-(diag\ G)^{-1}G^*]d\alpha-\alpha(diag\ G)^{-1}dG^*$. Assume that $d\alpha$ is negligible and that dG^* represents a fall in G_j^* of α/G_j units, all other G^*'s remaining constant. The effect of a one-unit rise in relative embodied factor trade in factor j is to raise at least one element of β (not necessarily β_j) by more than one and to decrease at least one other element of β.[3] For shifts in embodied factor trade due to home endowment shifts at constant prices, no such simple relationship is possible, since the λ matrix shifts. Finally, endowment shifts which lead to shifts in technology have no simple effect on β.

[2]This is the now-familiar algebra which generalizes the Stolper-Samuelson and Rybczynski theorems.

[3]Conditions sufficient to guarantee that β_j rises by more than one and that all others fall are discussed by Yasuo Uekawa, Murray Kemp and Leon Wegge.

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Cross-Section Tests of the Heckscher-Ohlin Theorem: Comment

By EDWARD E. LEAMER AND HARRY P. BOWEN*

In a recent article appearing in this *Review*, Jon Harkness suggests a method for testing the Heckscher-Ohlin factor abundance theorem with trade data from a single country. The Heckscher-Ohlin model implies that there is a special set of mathematical relationships among trade, factor intensities and factor abundance. A legitimate test of this model requires independent measures of these three concepts, and a subsequent computation of the extent to which these data violate the hypothesized set of mathematical relationships. However, an analysis such as Harkness', which uses measures of only two of these concepts, can be used to infer the third concept, but cannot be said to be a test of the model. Moreover, on the production side, the Heckscher-Ohlin relationships are a set of identities. The content of the theory derives from the assumed constancy of the factor intensities across countries which implies relationships among commodity outputs and factor inputs for all countries. It is of course impossible to test the constancy of factor intensities across countries with reference to data from a single country, and no test of the theory can rest on data from one country alone.

More specifically, Harkness errs in asserting that the sign and rank of partial regression coefficients obtained by regressing net exports on factor intensities will duplicate the factor abundance ordering implied by a Vanek-Bertrand model. This same error is implicit in the use of multivariate regression techniques by Robert Baldwin, William Branson and M. Monoyios, and others. Surprisingly enough, it was Harkness and John Kyle who earlier questioned the meaning of these cross-section regressions.

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I. Testing the Heckscher-Ohlin-Vanek Model

In order to facilitate our comment, we first restate the Heckscher-Ohlin-Vanek (H-O-V) Theorem in matrix form. Matrices and column vectors will be indicated by capital letters, scalars by lowercase letters, and the transpose of the matrix M by M'. The following notation will be used:

$T_i = n \times 1$ vector of the net exports by country i;

$E_i = m \times 1$ vector of factor endowments of country i;

$E = \Sigma_i E_i$;

$A_i = m \times n$ matrix of factor input requirements where the element a_{kj} indicates the amount of factor k used to produce one unit of commodity j in country i;

$Q_i = n \times 1$ vector of commodities produced in country i;

$C_i = n \times 1$ vector of commodities consumed in country i;

$Y_i = GNP$ of country i;

$Y = \Sigma_i Y_i$;

$B_i =$ trade balance of country i.

Outputs, inputs and factor intensities satisfy by construction the identities

$$A_i Q_i \equiv E_i. \tag{1}$$

Trade is related to outputs and consumption by the identities

$$T_i \equiv Q_i - C_i. \tag{2}$$

A. *The Heckscher-Ohlin-Vanek Theorem*

Given: (a) a competitive equilibrium with commodity price equalization, (b) constant

returns to scale production functions with nonreversible factor intensities for all goods, (c) identical technologies in all countries, (d) identical and homothetic preferences for all countries, (e) equal numbers of factors and goods,[1] and (f) incomplete specialization, then the input-output matrix A is the same for all countries, and endowments and trade are related by the set of equations

$$AT_i = E_i - Ew_i \tag{3}$$

where w_i is the scalar

$$w_i = (Y_i - B_i)/Y. \tag{4}$$

PROOF:

From these assumptions we obtain factor price equalization (see Paul Samuelson, 1948) and consequently identical input-output coefficients. Since all countries face the same prices, assumption (d) implies that they consume equal proportions of all commodities

$$C_i = Qw_i \tag{5}$$

where $Q = \Sigma Q_i$ is the world output vector and w_i is some scalar quantity. Thus (2), (1), and (5) imply (3):

$$AT_i = A(Q_i - C_i) = E_i - AQw_i = E_i - Ew_i.$$

The scalar w_i can be computed by premultiplying T_i by the vector of commodity prices P to calculate the trade balance

$$B_i = P'T_i = P'A^{-1}(E_i - Ew_i) = Y_i - Yw_i,$$

from which equation (4) is immediate.

In order to test this theorem, it would be necessary to obtain independent measures of A, T_i, and $E_i - Ew_i$, and to compute the extent to which these data violate the relationships (3). For example, Gary Hufbauer uses the U.S. input-output coefficients to compute the factors embodied in trade AT_i and correlates them across countries with measures of factor endowments.[2] Without a clear alternative theory, this kind of study is limited to statements of the form: the theory explains net trade in labor embodied in goods better than it explains net trade in capital embodied in goods.

Many studies which seem to be testing the theory are based on measurements of only two of the three concepts A, T, and E. In fact these studies take the theory as given and use the relationship (3) to derive measures of the third concept given the other two. Analyses such as Baldwin, Branson and Monoyios, and Harkness which make use of information about only A and T must be thought to be inferring the factor abundance $E_i - Ew_i$. Similarly, Leamer (1974) who uses measures of only T_i and E_i must be thought to be inferring the technology A. In neither case is the theory subjected to test.

When A and T are observed, the most direct way to estimate the factor abundance is simply to compute AT_i, the net trade in factor services, which theoretically is equal to the excess supply of factors, $AT_i = E_i - Ew_i$. The first to do this was Wassily Leontief who found for the United States in 1947 that the capital embodied in imports divided by the labor embodied in imports exceeded the capital embodied in exports divided by the labor embodied in exports. This finding has been called the "Leontief paradox" since it seems to imply that the United States was more abundant in labor than in capital. However, as discussed in Leamer (1980), the theory described by equation (3) implies a study of the net flow of factor services. When the correct calculations are made, the United States is revealed to have been relatively capital abundant.

Many researchers who have observed values of T_i and A do not in fact merely compute AT_i. Instead they regress the trade vector on the factor intensities:

$$T_i = A'\hat{\beta}_i + u_i$$

[1]This assumption is made to avoid cluttering this comment with a treatment of more complicated models.

[2]More accurately, Hufbauer uses ratios of a_{ij} (for example, the capital-labor ratio) to form measures of factors embodied in trade. Furthermore, equation (3) suggests that it is appropriate to do a multiple regression of factor content of trade on factor endowment *and* $(Y_i - B_i)/Y$ rather than Hufbauer's simple correlations.

where $\hat{\beta}$ is the $m\times 1$ vector of regression coefficients, u is the $n\times 1$ vector of residuals, and where the constant in the regression has been suppressed in order to maintain the number of parameters equal to the number of observations. It is claimed by all writers at least implicitly, and it is asserted by Harkness explicitly, that $\hat{\beta}_i$ has the same sign as the factor abundance vector $E_i - Ew_i$. This is not in fact a theoretical implication of the H-O-V Theorem. The vector $\hat{\beta}$ in fact is equal to $(AA')^{-1}AT_i$, which by the H-O-V equation is

$$\hat{\beta}=(AA')^{-1}AT_i=(AA')^{-1}(E_i-Ew_i).$$

The assertion that $\hat{\beta}$ and E_i-Ew_i have the same sign is mathematically equivalent to the assertion that the transformation matrix $(AA')^{-1}$ preserves the orthant of E_i-Ew_i. The assumptions in the H-O-V Theorem do imply that A is a positive matrix, but, except in the two-factor case, this is not sufficient to guarantee that $\hat{\beta}$ and E_i-Ew_i are in the same orthant.[3] We offer the following three-dimensional counterexample.

B. *Counterexample*

Suppose there are three factors: capital, labor, and land, and let the factor intensity matrix be

$$A=\begin{bmatrix} .8 & .2 & .9 \\ .2 & .8 & 0 \\ 0 & 0 & .1 \end{bmatrix}$$

where the first two (manufacturing) commodities do not require land in production, and the third (agricultural) commodity uses land and large amounts of capital but no labor. The inverse of this matrix is

$$A^{-1}=\begin{bmatrix} .8/.6 & -.2/.6 & -7.2/.6 \\ -.2/.6 & .8/.6 & 1.8/.6 \\ 0 & 0 & 10 \end{bmatrix}$$

[3]Clearly, the sign of the elements of the vector AT will be preserved if $(AA')^{-1}$ were a strictly positive diagonal matrix. In fact, this condition has recently been shown (see Bee-Yan Aw) to be necessary and sufficient to preserve the sign of all such vectors when there are more than two factors.

Suppose further that the endowment of the country is $E_i=(1.9,1,.1)$, whereas the world endowments are $E=(3.7,2.2,.1)$. Then, the country's output vector is $A^{-1}E_i=(1,1,1)$, and the world's output vector is $A^{-1}E=(3,2,1)$. If prices of the commodities are all equal to one and if trade is balanced, w_i is the *GNP* ratio, $w_i=3/6$, and the excess supply of factors of the country is $E_i-Ew_i=(.05,-.1,.05)$, that is, the country through its trade in goods is exporting capital and land services and importing labor services.

The trade vector, which is the difference between production and consumption, is

$$T_i'=(1,1,1)-1/2(3,2,1)$$
$$=(-.5,0,.5),$$

that is to say, the country exports the agricultural good for imports of the capital-intensive manufacturing good. If this trade vector is regressed on the intensity matrix, the estimated coefficients are

$$\hat{\beta}=(AA')^{-1}AT_i=(A')^{-1}T_i$$
$$=(-.4/.6,0,11).$$

The first coefficient, the capital coefficient, is negative even though the country is well endowed in capital. The second coefficient, the labor coefficient, is zero even though the country is poorly endowed in labor. What has happened here is that, although overall this country is well endowed in capital, net of the factors used in agriculture, capital is actually a scarce factor. That is, within the manufacturing sector, trade in the labor-intensive commodity is zero and the capital-intensive product is imported. In order to explain this manufacturing trade, we must set the capital coefficient, $\hat{\beta}_k$, to a negative number. Since the agricultural good is very capital intensive, the negative value of $\hat{\beta}_k$ has the tendency to predict that the agricultural good is imported. But this tendency is more than offset by the very large land coefficient. In summary, then, the agricultural exports are explained by choosing a large positive

coefficient for land, and since land does not enter into manufacturing production, the manufacturing trade is explained by choosing a negative coefficient for capital.

Actually, Harkness uses value data and scales the outputs such that the output level of each good is one. He then makes the very strong statement: "Given that factor complementarities can be controlled through multiple regression analysis, the H-O Theorem predicts that the sign and rank order of any multiple regression coefficient will duplicate those of the corresponding relative "actor endowment" (p. 784). Since the preceeding counterexample makes use of prices and output levels which are all unity, t applies also to the use of data in value erms, scaled by output levels. The consequent phrase in the quoted sentence is hereby demonstrated to be false; the somewhat unclear antecedent phrase may also be alse.

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Cross-Section Tests of the Heckscher-Ohlin Theorem: Reply

By JON HARKNESS*

The trade literature is replete with Vanek-type theorems which provide a simple, straightforward link between a nation's net (indirect) trade in factor services and her relative factor abundances. Of course, since factor services are traded only to the extent that they are embodied in commodities, there must also exist a further intimate connection, through factor intensities in production, to direct commodity trade. For example, in a many-goods, two-factor world with incomplete factor-price equalization, the rankings of commodities by net exports and by intensity of use of the relatively abundant factor will be identical.[1] This is the well-known Heckscher-Ohlin (H-O) Theorem. Nonetheless, with arbitrarily many factors, the link to commodity trade which Vanek-type theorems necessarily imply is neither so simple and straightforward nor, for that matter, particularly illuminating.

My 1978 paper was concerned, primarily, to characterize the missing link between commodity and factor-service trade and, thereby, between commodity trade and relative factor abundances in a form which preserves the spirit of the H-O Theorem from simpler, two-factor worlds. As a practical matter, I was also concerned to operate within the context of a set of assumptions which would permit direct empirical implementation of the model. Both Edward Leamer and Harry Bowen (L-B), and James Anderson attempt to demonstrate that, in fact, I failed in my search for the H-O-type missing link. Most of their comments are thoughtful and, on the surface, correct; but they in no way alter my original conclusions. There exists in these comments a serious misinterpretation of both the theoretic and the empiric content of my paper. Support of this assertion will require that I briefly review my argument.

First, I proposed a "relationship," soon to be defended, between net commodity exports and factor intensities of the following specific form:

$$(1)\quad x_n/y_n = \sum_{m=1}^{M} \hat{\beta}_m \cdot f_{mn} + \hat{e}_n; \qquad n=1,\ldots,N$$

where x_n and y_n are, respectively, net exports and output of the nth commodity; f_{mn} is the value share of the mth factor in producing the nth good; $N>M$; and, most important, $\hat{\beta}_m$ is an *OLS*-computed partial regression coefficient, derived from the multiple regression, across goods, of x/y on all f_m's. By implication, $\hat{e}_n$ is an *OLS*-computed "error" term.

The most important feature of (1), explicitly noted in my paper, is that it is a descriptive, not a structural, relation. It is meant solely and simply to characterize and to summarize the relationship between commodity trade and factor intensities which, on average, obtains in the general equilibrium. Hence, $\hat{\beta}_m$ is not a proposed structural parameter, in the conventional sense of being invariant across commodities, which we choose to estimate using *OLS* methods. Rather, it is an *OLS*-computed descriptive statistic summarizing the average, "partial" relationship between net commodity exports and the mth factor intensity. The main thrust of Anderson's comments derives from misinterpretation of (1) as a proposed conventional structural relation.

Anderson first attempts to show that there is no theoretic justification for expression (1). There is, but I must admit my original argument was heuristic and, in large part, implicit. Nonetheless, following him, assume as many factors as goods. Without loss of

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[1]See Ronald Jones as amended by Jagdish Bhagwati.

generality, we may also choose units such that each commodity output and each factor endowment is unity. Further, let g_m^0 be the net (indirect) export, as a proportion of total domestic supply, of the mth factor. Then, in his notation, E and F will be the column vectors with typical entries x_n/y_n and g_m^0, respectively, while θ will be the matrix of factor intensities with typical entry f_{nm}. Reproducing Anderson's equation (1):

$$F=\theta' E. \tag{2}$$

The column vector with typical entry $\hat{\beta}_m$ is defined by: $\hat{\beta}=(\theta'\theta)^{-1}\theta' E$. Thus,

$$\hat{\beta}=(\theta'\theta)^{-1}F. \tag{3}$$

Regardless of the numbers of factors and goods, (2) and (3) are definitionally true, as long as the technology matrix, θ, applies to all nations. However, when $N=M$, (2) can be rewritten as $F=(\theta'\theta)\theta^{-1}E$. Combined with (3), this implies

$$E=\theta\hat{\beta}. \tag{4}$$

But this is just Anderson's expression (4) in disguise and, moreover, is identical to equation (1) above, except that, here, the error term is zero because $N=M$. Consequently, contrary to Anderson, there is no inconsistency between (4) and (1).

He shows that, if there is a natural structural relationship between commodity trade and factor intensities, it is highly nonlinear, coming through the inverse of θ.[2] This is perfectly correct since $\hat{\beta}_m$ is not, nor was it ever alleged to be, a structural parameter. The exact structural relation between E and θ is quite complicated, being given by (4) where $\hat{\beta}$ itself depends on θ through the inverse matrix $(\theta'\theta)^{-1}$. But, this is not to the point since the theory relates only to $\hat{\beta}$ and not to any conventional, linear, structural relation between E and θ. My theory shows simply that, *ex post*, commodity trade can be characterized by an expression such as (1) or (4) where $\hat{\beta}$ is directly linked to factor-service trade F. In turn, according to Jaroslav Vanek, F is a positive monotone transform of the corresponding vector of relative factor abundances, given by (2) in my original paper. Hence, $\hat{\beta}$ is directly linked, solely via factor intensities, to relative factor abundances.

So far, expression (4) gives the theoretic link between $\hat{\beta}$ and F. This link is not particularly illuminating. From the viewpoint of my H-O Theorem, it is desired that $\hat{\beta}$ be a positive, monotonic transformation of F. As indicated by expression (3), as shown by L-B and as explicitly suggested in my paper, this is not the case, a priori.[3] Knowing this full well, my paper was concerned to impose additional, meaningful prior restrictions on the technology matrix θ which would produce the desired theorem.

Briefly, let B_m be the "total" regression coefficient computed from the simple regression, across goods, of x/y on f_m and let $C_m=\Sigma_{j\neq m}b_{jm}$, where b_{jm} is the computed coefficient from a simple regression of f_j on f_m. I showed that

$$B_m=g_m^0(1+C_m),\ m=1,\ldots,M, \tag{5}$$

where, recall, g_m^0 is the typical element of F. Hence, B_m is directly linked via *all* factor intensities to net trade in the corresponding factor service.

The coefficient B_m is analagous, but in no sense identical, to a total derivative. It summarizes the average overall relation of x/y to f_m deriving from two sources: a direct (or partial) relation and an indirect relation that accounts for variations in f_m, across goods, acting through f_j, for all $j\neq m$. This latter indirect relation comes through "factor complementarities"; that is, through possibly systematic (statistical) association, across goods, among factor intensities, as captured in C_m. Moreover, there is no reason to believe, a priori or a posteriori, that this indirect relation is unimportant. Contrary to Anderson's assertion, I did not impose the "highly restrictive" assumption that factor complementarities "do not matter." Far from it,

[2]J. R. Williams presents a full-blown version of the structural model used by Anderson.

[3]In a roundabout way, this is also the upshot of Anderson's remarks leading up to and including his discussion of the "magnification effect."

since the whole point of the exercise is to account for them so as to identify the partial relation of x/y to f_m.

The theoretic partial relation is easily derived. We perform the conceptual experiment in which, across commodities, all factor intensities save the mth are held constant. This would perfectly control for factor complementarities by making the mth and all other factor intensities mutually uncorrelated across goods in the experimental data. Given that domestic outputs and factor endowments have been scaled to equal unity, it is easy to see, according to (5), that the partial (and simple) *OLS* regression coefficient β_m^e computed under such experimental conditions will equal g_m^0. Combined with Vanek's result on g_m^0, my H-O Theorem follows: the sign and rank order of β_m^e will duplicate those of the corresponding relative factor abundance. So far, both L-B and Anderson agree with me in the sense that neither (5) nor its implications when factor intensities are mutually orthogonal is disputed.

In practice, unfortunately, neither can a controlled experiment be conducted nor are factor intensities mutually uncorrelated across goods. Nonetheless, the econometrician's analogue to the controlled experiment is, of course, multiple regression analysis (*MRA*) which, in my original words, "would *attempt* to remove the effects of collinearity" among factor intensities so as to produce a proxy for β_m^e. This analogy is all the more striking when it is recalled that the theory refers only and directly to $\hat{\beta}_m$. As is well known, the computed coefficient $\hat{\beta}_m$ from *MRA* allows for factor complementarities by adjusting the simple regression coefficient B_m for intercorrelations across goods among factor intensities. However, except when all such intercorrelations are zero, these adjustments will not perfectly duplicate the controlled experiment nor, therefore, will they necessarily remove the effects of factor complementarities in the theoretically appropriate manner suggested by (5). In fact, since β_m^e is not a conventional structural parameter, *MRA* can not even produce a (statistically) unbiased estimate.[4]

Nonetheless, I am not particularly concerned that $\hat{\beta}_m$ may be a poor proxy for $\beta_m^e = g_m^0$. From the viewpoint of my H-O Theorem, what matters is the ordinality, not the cardinality, of $\hat{\beta}_m$: I would be perfectly content were $\hat{\beta}_m$ merely to preserve the sign and rank order of $\beta_m^e = g_m^0$. It is in this limited sense that I would wish *MRA* to "control" for factor complementarities. As seen above, *MRA*'s attempt to exercise such control may fail, a priori, for an arbitrarily chosen technology matrix θ; it is at the mercy of the data. For example, *MRA* will fail (succeed), a posteriori, when existing factor intensities are perfectly collinear (mutually uncorrelated) across goods. However, between these two extremes, there will exist conditions under which factor complementarities would be sufficiently "mild" that $\hat{\beta}_m$ would proxy $\beta_m^e = g_m^0$ to the desired degree. Consequently, I assumed (implicitly, perhaps) that the statistical interrelations among technologies are such that these conditions hold in which case *MRA* can control, in the desired fashion, those factor complementarities *assumed* to exist.[5] My ultimate version of the H-O Theorem then follows: "*Given that factor complementarities can be controlled through MRA*" (p. 789), the sign and rank order of $\hat{\beta}_m$ will duplicate those of g_m^0 and thereby, according to Vanek, those of the corresponding relative factor abundance.

Leamer and Bowen purport to show that the theorem's conclusion does not follow from its (emphasized) assumption; but it obviously and almost trivially does. What, now can one make of their result? In fact, they have simply shown that the theorem's *assumption* would be false were existing factor complementarities sufficiently severe. But my assumption, itself, rules out this possibility.

[4]Given measurement errors in the data, we can hope at best to obtain an unbiased estimate of the "true" *OLS*-computed coefficient $\hat{\beta}_m$, which is in turn merely a proxy for the hypothetical direct coefficient β_m^e.

[5]At least Anderson, if not L-B, explicitly recognizes "controllability" as an assumption about the technology matrix θ, and not about *MRA*, per se. However, he does quite falsely attribute to me the assertion that this is "more or less equivalent to assuming" factor intensities are across goods mutually uncorrelated. While this would be sufficient, it is by no means necessary for controllability. Nonetheless, since collinearity may enter θ in quite indirect and complicated ways, no simple necessary condition for controllability emerges.

By choice of a counterexample, L-B violate my theorem's conditioning assumption; it is then not surprising that my conclusion does not follow.[6] Moreover, while less formal, my assumption on existing factor complementarities and, therefore, on technologies has exactly the same status as any other, such as perfect competition or identical, homothetic tastes and technologies, which form the base of the maintained hypothesis. The model is tested by the conformity of its predictions to the facts, not by the prior or posterior validity of its assumptions. In fact, the data support the model's H-O-type prediction. In the end, the proof of my pudding is in the eating!

Anderson is also concerned by possible specification bias. While I explicitly noted that the regression's intercept may be influenced by omitted variables, he claims: "Implicitly, [my] slope terms are not so influenced, since [I use] them to test the rank hypothesis without further comment. This is clearly false" (p. 1038). However, his concern is ill-founded and his claim is false.

The rank hypothesis comprises two assumptions and one definition. If the factor-shares matrix θ applies to all nations after trade, expression (3) is definitionally true, regardless of the underlying structural determinants of commodity trade. If, in addition, technology is such that, *ex post*, $(\theta'\theta)^{-1}$ is always a rank and sign preserving transformation, the rank hypothesis holds. Now, expression (3) simply says: *ex post*, $\hat{\beta}$ is directly linked, *mutatis mutandis*, to factor-service trade F, via factor intensities in accord with the H-O rank condition. Hence, the H-O Theorem *requires* that $\hat{\beta}$ incorporate, rather than eliminate, the influence on θ of all other possible determinants of commodity trade. A priori, the theorem would not hold on computed coefficients from a regression in which all variables save factor intensities were *not* omitted. In short, there is every good reason to limit the regressors to factor intensities. It should now also be apparent that Anderson is incorrect in later asserting that, because it alters θ, a home endowment shift has no predictable effect on $\hat{\beta}$. Given Vanek's theorem and the maintained assumption on $(\theta'\theta)^{-1}$, $\hat{\beta}_m$ will, regardless of shifts in θ, always ultimately preserve the sign and rank order of g_m^0 and its corresponding relative factor abundance obtaining in the new general equilibrium. Such would also be the case, of course, for shifts in *any* underlying structural variable.[7]

Misspecification is, however, a meaningful problem when it comes to equation (1)'s "predictive" ability. Suppose there exists an omitted variable with an important systematic influence across goods on x_n/y_n. The absolutely more (less) is this variable correlated with any factor intensity(s), the better (worse) will the regression fit the data. As I explicitly noted (p. 798), my very good fit suggests that omitted variables, if any, are highly collinear with factor intensities in which case their influence is captured in $\hat{\beta}$. Of course, this does not permit one to identify important omitted variables, if any, nor to test their separate influence on net commodity trade. But, contrary to Anderson, I never claimed to be testing alternate trade theories.[8] Rather, I tested the factor-proportions model's prediction that net commodity trade can be characterized by reference solely to *ex post* factor intensities. The facts are consistent with this view, while not precluding the possible coexistence of other structural determinants of commodity trade.

Finally, according to my H-O Theorem, the hypothetical rank correlation coefficient ρ between the elements of the vectors F and $\hat{\beta}$ is unity. Anderson therefore argues I should have tested against the null hypothesis that ρ is unity, not zero. Unfortunately, no such legitimate tests exists, since the sampling distribution of Spearman's (or Kendall's) rank

[6]The L-B factor complementarities are particularly severe. Agriculture is the sole user of the (relatively) least abundant factor, the most intensive user of the most abundant factor, and a nonuser of the middling abundant factor. I suspect the effects of such complementarities would be greatly moderated as the number of goods expands relative to the number of factors and when each good uses (directly or indirectly) some of every factor.

[7]Including transport costs, tariffs, or quotas since neither the H-O nor the Vanek Theorem necessarily imply complete product and/or factor-price equalization.

[8]Just as, contrary to L-B, I never claimed to be testing Vanek's theorem.

correlation coefficient r is unknown when the true coefficient ρ is not zero. His test of the null that $\rho=1$, while favorable to my theory, is not valid for it uses an estimated variance for r, $(M-1)^{-1}$, which implicitly assumes ρ is zero, not unity. Even in those very special cases where r's *asymptotic* distribution is known, M. G. Kendall and Alan Stuart strongly advise against testing any null hypothesis other than $\rho=0$, especially with my sample size of only eighteen. In any event, Anderson suggests ordinary, not rank, correlation is the appropriate measure of association between F and $\hat{\beta}$. This would be true only were $\hat{\beta}_m$ an unbiased estimate, not simply a rank-preserving proxy, of the hypothetical coefficient, $\beta_m^e = g_m^0$.

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Do Union Members Receive Compensating Wage Differentials? Note

By DUANE E. LEIGH*

In a recent article in this *Review*, Greg Duncan and Frank Stafford (hereafter, D-S) provide an intriguing theory explaining observed union-nonunion wage differentials as compensating differentials for undesirable working conditions. The underlying premise of their model is that in production settings characterized by worker interdependence and a large capital stock per worker, some mechanism is required to reconcile diverse worker preferences with the need to coordinate hours and pace of work. Unions serve this function by identifying worker preferences and bargaining for wages sufficiently high to compensate for restrictions on personal choice imposed by shared working conditions.

This comment reports the results of an additional test of D-S's "interdependencies hypothesis" using data for young men from the National Longitudinal Surveys (*NLS*). These results fail to replicate the longitudinal evidence provided by D-S. Rather, the findings presented here are more reasonably interpreted in terms of the collective voice function of unionism in altering onerous working conditions.[1]

I. Duncan and Stafford's Empirical Evidence

Duncan and Stafford present two kinds of evidence in support of their model. First, cross-section results (using the 1975–76 Time Use Survey) show that estimated union wage differentials are sharply reduced when working conditions variables are added to wage equations estimated for blue-collar workers.[2] Second, longitudinal data from the Panel Study of Income Dynamics (*PSID*) are utilized to compare changes over time in wage rates and working conditions for blue-collar workers who changed union status. Working conditions are measured by an index representing choice in doing work and a dummy variable which captures freedom to increase hours of work. D-S find that workers joining unions enjoyed the largest wage increase between 1968 and 1971, but at the expense of the largest decline in desirable working conditions. Conversely, workers quitting union jobs had the smallest average wage increase but the highest gain in reported choice in work.

Use of longitudinal rather than cross-section data appears to be the more promising approach to providing a further test of the D-S model. The principal difficulty with a cross-section approach is the generally inconclusive results obtained in most attempts to estimate compensating wage differentials for job characteristics other than risk of death. As is made clear in recent surveys by Charles Brown and Robert Smith, D-S's evidence that working conditions variables command a wage premium is the exception rather than the rule.[3] Smith (p. 347) com-

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[1] Channels of collective voice in unionized firms (for example, contract negotiations and grievance-arbitration procedures) are discussed in detail in Sumner Slichter, James Healy, and Robert Livernash. More recently, Richard Freeman (1976, 1978, 1980) has emphasized collective voice mechanisms in analyses of the nonwage effects of unions.

[2] These data, as well as cross-section data from the Quality of Employment Survey, are also used to estimate the effect of working conditions variables on union membership.

[3] D-S (p. 365, fn. 23) reach the same conclusion. In connection with results obtained for white-collar workers, they suggest (p. 370) that failure to observe compensating wage differentials is probably due to the omission of important but unmeasured skill variables. An extention of D-S's cross-section approach to deal with the omitted-variable problem is to use longitudinal

ments that failure to find convincing evidence of compensating wage differentials should not be surprising given serious problems of comparability across individuals in self-reported data and of specifying disagreeable working conditions in the face of heterogeneous tastes. The working conditions variables utilized by D-S are self-reported, as are *NLS* measures of working conditions.

Relative to cross-section data, longitudinal data permit a more direct test of the interdependencies hypothesis by allowing a comparison of wages and working conditions for the same individual as a union member and as a nonunion worker. But while *PSID* data are generally consistent with the hypothesis, D-S's (pp. 363, 369) statements that their longitudinal findings represent "strong" evidence of compensating wage differentials would be more convincing if supporting evidence could be provided using alternative data sets. The next section describes the working conditions variables available for young male *NLS* respondents.

II. *NLS* Data for Young Men

To be of use in testing D-S's interdependencies hypothesis, a longitudinal data set must include a sufficiently large proportion of individuals changing union status to allow meaningful analysis. The young men *NLS* sample satisfies this criterion since young workers change employers, and thus union status, relatively frequently. (*NLS* respondents ranged between 24 and 34 years of age in 1976.) Union status is measured by whether or not a respondent's wage in his current job is set by a collective bargaining contract.

The working condition variables are constructed from a series of retrospective questions posed in 1976 asking respondents how they feel about their present job in comparison to the job they held five years earlier. The specific questions include the following:

1. So far as work is concerned, do you think that you have progressed, moved backward, or just about held your own over the past five years?
2. Over the past five years, would you say that the pressures you feel on the job have increased, decreased, or remained about the same?
3. Over the past five years, has there been any change in your ability to keep up with the pace of your job?
4. Over the past five years, has the amount of fatigue you feel at the end of a workday increased, decreased, or remained about the same?

The third of these questions addresses directly an aspect of work described by D-S as requiring a compensating wage differential. Note that workers are not asked whether the pace of work they face changed between 1971 and 1976. Rather, they are asked whether they have to work harder now than five years earlier to keep up with the work pace. From the perspective of the utility attached to work, change in ability to keep up with the pace of one's job may be more relevant than a change in work pace that is matched by a change in ability to keep up.

While pressures felt at work and level of fatigue at the end of the workday should be (inversely) related to the degree of freedom enjoyed at work, responses to these two questions are likely to be affected by additional nonpecuniary aspects of work. The pleasantness or unpleasantness of the workplace, for example, involves a public goods problem and is thus directly relevant to the D-S model. Moreover, other nonpecuniary aspects of the workplace that might affect job pressures and fatigue such as intensity of supervision and responsibility for the work of others appear to be closely related to such variables used by D-S in their empirical analysis as work effort (from the Time Use Survey) and "requiring hard work," "physical effort," and "allowing decision making" (from the Quality of Employment Survey).

data to estimate wage change equations which control for person-specific quality characteristics that do not change over time. This extension is not pursued here or by D-S. However, Brown's results using individual-specific intercepts indicate that even with superior control for variation in worker quality, compensating wage differentials for undesirable working conditions are not apparent.

TABLE 1—CHANGE IN FEELINGS ABOUT WORK AND WAGES BETWEEN 1971 AND 1976, BLUE-COLLAR WORKERS, BY CHANGE IN UNION STATUS[a]

Change between 1971 and 1976	Remained Union	Remained Nonunion	Joined Union	Left Union	All Workers
Progress at work:					
Progressed	.624	.618	.664	.583	.622
Held own	.334	.315	.283	.313	.317
Moved backward	.041	.067	.053	.104	.061
Opinion of job pressures:					
Increased	.390	.436	.407	.469	.423
Remained about same	.469	.420	.407	.333	.425
Decreased	.141	.143	.186	.198	.153
Ability to keep up with job pace:					
Harder	.052	.065	.071	.052	.060
No change	.824	.820	.832	.813	.822
Easier	.124	.115	.097	.135	.118
Level of fatigue at end of work day:					
Increased	.252	.261	.204	.302	.256
Remained about same	.638	.620	.646	.573	.624
Decreased	.110	.119	.150	.125	.121
Hourly wages:					
Absolute change	$2.64	$1.87	$2.82	$1.42	$2.16
Percentage change	70.6	81.0	117.7	44.9	78.6
Number of observations	290	495	113	96	994

[a]Totals may not sum to 1.000 due to rounding error.

"Progress at work" is a sufficiently open-ended concept that answers to this question may be subject to a variety of interpretations. A reasonably general interpretation is that progress at work is closely related to the job satisfaction measures analyzed by George Borjas, Freeman (1978), and Daniel Hamermesh. Responses that a worker "likes," "is satisfied with," or "enjoys" his job should be strongly correlated with a feeling that he has progressed in his work. The retrospective nature of all four questions subjects them to the usual doubts about respondents' ability to recall accurately the characteristics of jobs held at an earlier time. Retrospective information, on the other hand, offers the advantage that responses are not subject to the problem that worker preferences change over time raising the possibility that basically the same set of working conditions may be evaluated differently by a given worker interviewed at different points in time. This problem is expected to be especially acute for the young, highly mobile workers most likely to change union status.

Table 1 presents distributions of responses to the working conditions variables by union status change categories. Also shown are mean changes in wages expressed in absolute and percentage terms. Only workers employed in blue-collar occupations in 1971 are included in the sample. Other restrictions are that respondents must not be enrolled in school in 1971 and 1976, and that they must report a wage and be employed in either the private or government sector in both years. Of the resulting sample of 994 *NLS* respondents, 21.1 percent changed union status between 1971 and 1976. The comparable figure for D-S's *PSID* sample is 14.2 percent of 1356 respondents.

Looking first at union joiners and leavers, workers who moved from nonunion to union employment clearly enjoyed a much larger absolute and percentage increase in wages than workers who moved from union jobs. Duncan and Stafford report a similar and equally dramatic difference between union joiners and leavers. In contrast to their findings concerning change in working conditions, however, there is little evidence for *NLS* respondents of deterioration in feelings about work for union joiners and improvement in feelings about work for union leavers. In fact, those who moved from union jobs are somewhat more likely to report an in-

crease in job pressures and level of fatigue than those who moved to union jobs. It should be noted, nevertheless, that a conventional *chi*-square test of independence between each of the working conditions variables and change in union status resulted in failure to reject the null hypothesis of independence at customary levels of significance.[4] With respect to the work pace variable, more than 80 percent of workers who changed union status (as well as of union and nonunion stayers) experienced no change in their ability to keep up with the pace of work. Proportions of responses other than "no change" are quite similar across categories of change in union status.

Responses to the progress at work question indicate that over 90 percent of the sample felt they at least "held their own" between 1971 and 1976, a result which is consistent with evidence provided by Freeman (1978) showing that most workers are reasonably well satisfied with their jobs. Among workers who changed union status, those who joined unions seem more likely to report that they progressed and less likely to indicate moving backward than union leavers. Progress at work is positively correlated with wage change, however; and it would be desirable to examine the impact of union status change on progress at work holding constant the effect of wage change.

Among workers holding union or nonunion jobs in both 1971 and 1976, those in union jobs enjoyed a larger absolute increase in wages than nonunion stayers but a smaller percentage increase. The same finding is reported by D-S. Distributions of responses for the working conditions variables are very similar for union and nonunion stayers, except that nonunion stayers may be somewhat more likely than union stayers to indicate an increase in job pressures.

III. Additional Results

Since the D-S model applies specifically to industrial unionism, one extension of the analysis presented in Table 1 is to examine change in feelings toward work for blue-collar workers who shifted to and from jobs covered by industrial unions. *NLS* respondents who answered "yes" to the collective bargaining question were asked to indicate the type of union or employee association that represents them in bargaining. The six possible union categories are condensed here to two categories: industrial unions and "other" unions.[5] Individuals who responded that they were covered by a union but who failed to indicate the type of union were dropped from consideration, leaving a sample of 950 individuals.

Since industrial union workers represent less than half of all union workers in both years, proportions of the sample who joined and left industrial union jobs are only 7.3 and 6.1 percent, respectively. Subject to this qualification, patterns of responses to the working conditions questions for industrial union joiners and leavers echo those shown in Table 1. In particular, workers who moved from industrial union jobs to nonunion employment or jobs covered by a nonindustrial union are more likely to report increases in fatigue and especially job pressures than workers who shifted to industrial union jobs. Also consistent with Table 1, industrial union joiners enjoyed a much larger wage increase in both absolute and percentage terms than leavers.

A second extension is to examine the impact of shifts in union status on change in feelings about work holding constant the effect of other variables expected to affect working conditions. Assume that change in working conditions ($\Delta CONDS$) between 1971 and 1976 is determined for individual i by a simple relationship of the form

$$(1)\quad \Delta CONDS_i = a_0 + a_1 \Delta U_i + a_2 \Delta X_i + e_i$$

where $\Delta CONDS_i$ represents the four *NLS* working conditions variables; ΔU_i is change in union status; ΔX_i is change in a vector of control variables including dummy variables

[4]Similarly, calculation of the *eta*-squared statistic used by D-S indicates that change in union status explains little of the variation in *NLS* working conditions variables.

[5]Other unions include craft unions, government worker (excluding teachers) and white-collar unions, nonidentifiable national unions, local unaffiliated unions, and nonclassifiable unions.

TABLE 2—ESTIMATES OF THE EFFECT OF CHANGE IN UNION STATUS ON CHANGE IN FEELINGS ABOUT WORK, BLUE-COLLAR WORKERS[a]
(Standard Errors in Parentheses)

	Progress at work		Job Pressures		Job Pace	Fatigue
Explanatory Variables	(1)	(2)	(3)	(4)	(5)	(6)
USTAYER	−.041	−.099	−.115	−.143	−.059	−.046
	(.056)	(.056)	(.062)	(.062)	(.055)	(.062)
UJOINER	.070	−.007	−.055	−.092	.072	−.084
	(.076)	(.075)	(.083)	(.084)	(.074)	(.083)
ULEAVER	−.099	−.053	−.017	.005	−.046	.077
	(.082)	(.081)	(.090)	(.090)	(.080)	(.090)
Schooling	.061	.053	.021	.017	−.019	−.011
	(.012)	(.012)	(.013)	(.013)	(.012)	(.013)
Δ Schooling (=1 for years beyond 1971 level)	.061	.072	.086	.091	−.031	−.105
	(.050)	(.049)	(.054)	(.054)	(.049)	(.055)
Nonwhite	−.191	−.149	−.213	−.193	−.164	−.233
	(.052)	(.052)	(.057)	(.057)	(.051)	(.057)
Δ Wage		.086		.041		
		(.013)		(.015)		
R^2	.065	.101	.030	.038	.027	.030

[a]Other explanatory variables included in the equations are 1971 age, change in major occupation, change in major industry, and change in region. Dependent variables are measured as Z scores.

measuring change in years of schooling, change in major occupation, change in major industry, and change in region (North-South migration);[6] and e_i is a random disturbance term. Race (=1 if nonwhite), age in 1971, and years of schooling completed as of 1971 are also controlled for in the analysis. Because the effect of a change in union status may depend on initial union status, ΔU_i is decomposed into the following dummy variables: union coverage in both years (*USTAYER*), union coverage in the first year but not the second (*ULEAVER*), nonunion status in the first year but union coverage in the second (*UJOINER*).

Since the categories of each of the working conditions variables have an a priori ordering, it is possible to follow Freeman (1978) by rescaling the variables according to a specific symmetric probability distribution. Applying the unit normal transformation, each dependent variable becomes a Z score measuring the number of standard deviations between a given response and the mean.[7]

Table 2 displays estimates of the effects of change in union status and of selected other variables on the rescaled measures of working conditions. Columns (1) and (2) and columns (3) and (4) differ by the addition of an explanatory variable measuring the absolute change in wages. Estimated coefficients on *UJOINER* and *ULEAVER* are seen to be frequently exceeded by their standard errors. Taking these point estimates at face value, however, union joiners are more likely than union leavers to experience reductions in job pressures and fatigue.[8] Only for the job pace variable are union joiners observed to suffer

[6]As it is difficult to separate union membership from job choice decisions, inclusion of the three dummy variables measuring employment shifts in (1) was expected to reduce the estimated impact of ΔU_i since part of the effect of a change in union status would be captured by one or more of these dummies. In fact, there did not appear to be much difference in results for the change in union status categories whether or not the additional dummy variables were included in the regressions.

[7]A useful discussion of the issues and qualifications involved in transforming ordinal responses into cardinal measures is found in Krishnan Namboodiri, Lewis Carter, and Hubert Blalock, pp. 475–81.

[8]It is interesting to note that D-S (p. 370) find using Quality of Employment Survey data that workers reporting jobs that require "you to work very hard" are significantly less likely to be union members than other workers. D-S are unable to provide an explanation for this finding, but it does appear to be consistent with the result that union leavers experience an increase in fatigue relative to union joiners.

a possible worsening of working conditions relative to union leavers.

Among workers whose union status is the same in 1971 and 1976, the negative coefficient estimates on *USTAYER* in the first two columns suggest that union stayers feel that they failed to progress in their work in comparison to nonunion stayers, especially when the effect of wage change is held constant. On the other hand, union stayers are less likely than nonunion stayers to indicate increased job pressures. Although the coefficient estimates on *USTAYER* in columns (5) and (6) are not significant at customary levels, some indication is provided that union stayers are also less likely than nonunion stayers to report a harder job pace and increased fatigue.

Turning to the control variables, estimated coefficients on initial schooling and change in schooling indicate that greater schooling both across individuals and for the same individual results in access to jobs in which workers feel their work has progressed and which offer an easier job pace and reduced fatigue. Nevertheless, the schooling variables are positively related in increased job pressures. As expected, a positive relationship appears between the wage change variable and progress at work; and wage change is also positively related to increased job pressures. Perhaps the most surprising results appearing in the table involve the race variable. Nonwhites are found to be less likely than whites to report that they progressed in their work, but they are also less likely than whites to indicate increases in job pressures, job pace, and fatigue.

IV. Discussion

Empirical analyses utilizing self-reported measures of working conditions should be viewed with a healthy dose of skepticism. With this in mind, two conclusions may be drawn from the findings presented here. First, D-S's longitudinal evidence showing that higher union wages represent a compensating differential for undesirable working conditions does not generalize to *NLS* data for young men. Second, the *NLS* evidence appears to be more consistent with a collective voice view of unionism than it is with the interdependencies hypothesis advanced by D-S. In particular, results obtained for union joiners and leavers indicate that working conditions in the union sector are at least equal to those in nonunion jobs, as would be expected if, despite their higher wages, organized workers have a direct impact through their unions in altering disagreeable working conditions. Moreover, individuals who remain in union jobs are found to enjoy a decrease in job pressures in comparison to nonunion stayers even though they are less likely to report, holding change in wages constant, that they made progress in their work. This last finding lends credence to Freeman's (1978, pp. 139–40) paradoxical evidence that unionism reduces quits while at the same time decreasing job satisfaction. A union voice interpretation of these results is that channels of collective voice encourage the expression of dissatisfaction while simultaneously restraining dissatisfied workers from leaving their employers.

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An Economic Model of Teaching Effectiveness

By ANTHONY K. LIMA*

The literature on the determinants of good teaching performance has been largely devoted to empirical measurement. A complete review of the publications in this area would require at least an entire issue the size of this journal. Yet, it is virtually impossible to discover attempts to derive hypotheses about the determinants of good teaching from explicit models of behavior. This has led researchers into the trap of exploring only the empirical determinants of good teaching performance. Typically, the results of student evaluations are correlated with affective personality traits of the teachers, with peer evaluations of psychological compositions, or even with the results of various psychological tests. Examples are the works of Robert Isaacson et al., Frank Costin et al., and Wilbert McKeachie et al. In most of these studies, no substantive conclusions are reached regarding the determinants of effective teaching. In the few studies which do contain significant findings, the independent variable in question is difficult to explain as a direct determinant of teaching effectiveness. For example, Isaacson et al. find that virtually the only statistically significant determinant of effective teaching is the personality characteristic which they label "culture." This may imply that simply wearing a tweed jacket and taking up pipesmoking is sufficient to improve teaching.[1]

This paper takes a somewhat different approach to the analysis of teaching. Assume that the individual in question wishes to maximize teaching effectiveness. Clearly, there are constraints on this maximization process. One must necessarily be the time budget constraint. A second constraint, however, adds a good deal of interest to the model. This constraint is best described as the bundle of characteristics available to the individual. These characteristics could be termed the components of the individual's personality. Such attributes include physical appearance, psychological makeup, speaking ability, and a myriad of other variables. Thus, this model bears a resemblance to the standard economic models of monopolistic competition (see A. Michael Spence).

Before proceeding to a formal statement of the problem, a philosophical issue must be addressed. What is meant by "teaching effectiveness"? Generally, this is interpreted as maximizing student evaluations of teachers. However, this is clearly not always equivalent to maximizing student learning. Unfortunately, the latter variable is difficult (but *not* impossible) to measure. (Pre- and post-testing with standardized tests is becoming increasingly accepted, for example). The meaning of teaching effectiveness in this paper must, unfortunately, remain ambiguous. Some teachers (concerned, perhaps, with obtaining tenure) will interpret good teaching as obtaining good evaluations, the criterion by which they are judged. Others may take a more eclectic viewpoint. Since the problem below is an individual maximization problem, the precise definition of effective teaching may simply vary from individual to individual (see W. R. Allen).

Formally, this problem is exactly analogous to one first addressed by Kelvin Lancaster. He assumes that the consumer attempts to maximize satisfaction through purchase of bundles of attributes. Each commodity is possessed of certain of these characteristics. By consuming various combinations of these commodities, the consumer is

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[1]In a previously unreported experiment in the department of economics, California State University-Bakersfield, faculty members were required to wear coats and ties in classes. It was subsequently observed that teaching evaluations improved. Unfortunately, no detailed statistical results of this experiment are available for analysis.

able effectively to consume the particular combination of attributes desired.

Technically, the overall problem for the individual is to maximize his utility function. Maximization of teaching effectiveness is a subsidiary problem. The utility function depends on a variety of factors, such as research, administrative and committee work (negative utility), good teaching, consulting, and leisure. The model presented below is a labor supply model analogous to both of the above threads in the literature. For the individual, the simplied problem can be stated as

$$(1) \qquad Max\ U = U(E, y_1, \ldots, y_m),$$

subject to

(a) $T(E, y_1, \ldots, y_m) = \bar{T}$;

(b) $E = E(x_1, \ldots, x_n)$;

(c) $x_i \leqslant \bar{x}_i,\ i = 1, \ldots, n.$

where

$U \equiv$ the individual's utility function;

$E \equiv E(x_1, x_2, \ldots, x_n)$ is the individual's teaching effectiveness function;

$x_i \equiv$ the amount of characteristic i chosen by the individual to contribute to teaching effectiveness;

$\bar{x}_i \equiv$ the maximum amount of characteristic i available to the individual;

$y_1 \equiv$ research activity;

$y_2 \equiv$ administrative activity;

$y_3 \equiv$ consulting activity;

$y_4 \equiv$ leisure activity;

$T(E, y_1, \ldots, y_m) \equiv$ the time functions;

$\bar{T} \equiv$ maximum time available to the individual.

To solve problem (1), the usual Lagrangean method will be employed (see Michael Intriligator):

$$(2) \qquad \Lambda = U(E, y_1, \ldots, y_m) + \lambda(\bar{T} - T) + \sum_{i=1}^{n} W_i(x_i - \bar{x}_i + s_i)$$

where the s_i are the n slack variables. The utility function is conveniently rewritten in reduced form as $U = U(x_1, \ldots, x_n, y_1, \ldots, y_m)$. Thus, the Kuhn-Tucker conditions are

$$(3a) \qquad \partial U/\partial x_i - \lambda(\partial T/\partial x_i) + W_i \leqslant 0; \quad i = 1, \ldots, n.$$

$$(3b) \qquad [\partial U/\partial x_i - \lambda(\partial T/\partial x_i) + W_i] x_i^* = 0; \quad i = 1, \ldots, n.$$

$$(3c) \qquad \partial U/\partial y_j - \lambda(\partial T/\partial y_j) = 0; \quad j = 1, \ldots, m.$$

$$(3d) \qquad \lambda \geqslant 0$$

$$(3e) \qquad W_i \geqslant 0; \quad i = 1, \ldots, n.$$

$$(3f) \qquad W_i[x_i^* - \bar{x}_i + s_i] = 0.$$

$$(3g) \qquad T = \bar{T}.$$

$$(3h) \qquad x_i^* \geqslant 0.$$

$$(3i) \qquad x_i^* - \bar{x}_i + s_i \leqslant 0.$$

There is an apparent technical difficulty with this approach. If the characteristic in question contributes positively at all levels of effective teaching, then the solution to one part of the above problem is clearly for the individual to set $x_i = \bar{x}_i$ for all characteristics which he possesses. This problem does not exist in model (1) for two reasons. First, for a particular individual, certain characteristics may contribute positively to effective teaching only up to a certain level. Beyond that level, these characteristics may detract from teaching. For example, a sense of humor is often cited as a "good" characteristic. However, a teacher with an extremely well-developed sense of humor would not find teaching effectiveness enhanced by spending the entire class time telling jokes. (It must be noted, however, that jokes are unlikely to do any harm).

The second answer to this question is a bit less obvious. Certain characteristics may exhibit negative complementarity. That is, they may simply not "fit" well together. For example, an instructor who wears a tweed jacket and smokes a pipe will probably not find that telling obscene jokes in class enhances

his teaching. It may be important to present a consistent image. Therefore, it may be unwise for the individual to use each characteristic to the fullest extent available.

Finally, it should be noted that the problem as presented is extremely difficult to solve, even if the E and U functions are known. The only simple analytic solutions which exist will be for the (unrealistic) case in which E is a linear function of the x_i and U is linear. (See George Dantzig.)

The first-order conditions (3) imply one usual and one unusual result. As is well known, equation (3c) implies that the individual will equate the ratio of marginal utility to marginal time requirements across all "major" activities. For example:

$$(4) \quad \partial U/\partial y_i/\partial T/\partial y_i = \partial U/\partial y_k/\partial T/\partial y_k.$$

However, for teaching effectiveness, the model implies

$$(5) \qquad \frac{\partial U/\partial y_i}{\partial T/\partial y_i} = \frac{\partial U/\partial x_i + w_i}{\partial T/\partial x_i}.$$

This implies that the marginal utility from using characteristic i must be corrected for the "cost" of that characteristic in terms of using all of it (w_i) or, alternatively, the cost of using any more of it (if $s_i > 0$).

Another way of viewing this is to consider an individual utilizing all of characteristic g and less than the total available of characteristic h. For characteristic g, $W_g > 0$ and $S_g = 0$. Therefore, the marginal utility from using one more unit of that characteristic will be lower than would be the case if the constraint were not present. For characteristic h, $W_h = 0$, $S_h > 0$, and the individual is using less of the characteristic, than is available. In this case, he is at a maximum with respect to the particular characteristic.

Different individuals will probably adopt differing teaching styles. This will occur for five reasons. First, differing individuals have different endowments of qualities ($\bar{x}_i$'s). In other words, what works for one teacher will not be feasible for another, since they have different personality characteristics. An informal, discussion-type classroom style will simply not work for an individual who is not comfortable in that sort of situation. Such an individual will probably adopt a more structured approach to lectures.

The second reason for the difference in teaching skills will be the nature of the teaching effectiveness function. Different individuals will have different perceptions of what constitutes good teaching. This implies that they will place different values on personality characteristics, and will therefore consciously adopt different styles.

The third reason, of course, is that utility functions will differ from individual to individual. If one individual places a good deal of emphasis on effective teaching and another individual emphasizes research, they will probably adopt (markedly) different teaching styles.

The fourth reason is somewhat more technical. However, it is apparent with a little reflection that the E function will probably not have a unique maximum. Even given the constraints, there is no reason to expect that two identical individuals will adopt identical teaching styles. This is strongly related to the one finding which virtually all of the empirical literature supports: teachers can improve their teaching skills if they are given feedback on their strong and weak points. This feedback process will ultimately result in an increase in $\bar{x}_i$ for some of the x_i. Thus, good teaching is a learning process. As such, the above static model abstracts from the dynamic nature of the process of developing effective teaching. One plausible model is that the development of teaching skills is simply a stochastic learning process. That is, the individual begins with some model of what a good teacher does in the classroom (subject to the limitations of available characteristics, of course). He receives some feedback on what has worked and what has not worked. He then reduces or does not use fully some characteristics which have not worked, and develops some other characteristics which may work. As more feedback is received, another correction would be made. Through this trial and error process, the teacher learns how to be a better teacher. Thus, it is apparent that, if the E function has multiple optima, the stochastic nature of the learning process virtually guarantees that different optimums will be achieved by different individuals.

Finally, in order to progress in an academic environment, the faculty member must be aware of the weights placed on typical faculty achievements by evaluation committees. Some universities heavily reward publications, others stress teaching, and still others general university community involvement. Thus two individuals with equal $\bar{x}_i$ may well develop different teaching styles based upon the expected rewards at their respective universities.[2]

This model suggests that there is no reason to expect that different teachers will have the same mode of teaching. This has the (unfortunate) further implication that individuals doing research into the empirical determinants of teaching effectiveness are doomed to be searching through a haystack which simply contains no needle. If, in fact, different styles are effective for different individuals, it would be expected that a cross-sectional correlation analysis would give only insignificant results. In fact, the expected value of the correlation coefficients would be near zero (see Henri Theil). Therefore, under the present model, there is no reason for even continuing the search for "the" determinant of good teaching.

While this conclusion is undoubtedly depressing to academic researchers, it is immensely hopeful for future teachers. The model presented in this paper seems to indicate that most individuals who wish to become effective teachers can do so if they are given regular, constructive feedback and the opportunity to practice different styles. The empirical prediction from this model is that new teachers are likely to show the most dramatic improvements in teaching effectiveness, since they are testing different styles to determine what works for them. However, not much improvement should be shown by teachers who have been active in the profession for some length of time. Thus, for one of the few times in economics, researchers have been looking at cross-sectional data when time-series data would have been more appropriate.

To summarize the conclusions of this paper, a model has been presented which suggests that different equally effective teachers will adopt different teaching styles due to different endowments, differing perceptions of what constitutes good teaching, and different search paths to determine which of the available styles works for them. The model explains the absence of empirical findings on the subject of teacher effectiveness, and suggests that the search for empirical results should be spent on the study of new entrants to the teaching profession who are traced and evaluated for several years, rather than simply looking at panels of teachers at one point in time. Finally, the model suggests that learning is an important component of effective teaching, and that good learners are likely to become good teachers if they set that goal for themselves.

[2]This model ignores another factor which is undoubtedly significant. This can best be characterized as the "audience" factor. For example, effective teaching to a graduate economics class would probably be totally ineffective in an undergraduate rhetoric course. There is room for further research in this area.

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On the Mark: Comment

By STEPHEN E. HAYNES AND JOE A. STONE*

In a recent paper in this *Review*, Jeffrey Frankel develops a real interest rate differential version of the monetary or "asset" model of the exchange rate (hereafter referred to as *RID*) that combines "the Keynesian assumption of sticky prices with the Chicago assumption that there are secular rates of inflation" (1979, p. 610). He attempts to discriminate his model from Keynesian and Chicago special cases by examining the signs on the coefficients of four explanatory variables—relative money supply, relative income, the nominal interest rate differential, and the expected long-run inflation rate differential. Upon examination of monthly U.S.-German data from July 1974 to February 1978, Frankel concludes that the evidence supports *RID* over the Keynesian and Chicago special cases.

Attempts by Rudiger Dornbusch (1980) and Frankel (1980a) to use the monetary approach to explain movements in the mark-dollar exchange rate after February 1978, however, have been unsuccessful, showing insignificant coefficients and a "reversed sign" on the relative money coefficient. Frankel interprets this as evidence of the "collapse in the explanatory power of the monetary model" (1980b, p. 7). In response to this apparent collapse, both Frankel (1980b) and Dornbusch (1980) specify and estimate modifications of *RID*—the former by adding wealth to the money demand function in *RID*, the latter by modeling the impact of the current account within rational expectations and portfolio balance frameworks. Each contends, based on empirical evidence, that his modifications improve the standard monetary models.

Here, we argue that the above empirical tests of exchange rate models are inappropriate and misleading because the explanatory variables are specified in difference form (for example, the logarithmic difference between German and U.S. money supplies). Such subtractive linear constraints are especially dangerous because the specification bias which in general results from the restriction often leads to a sign reversal in the constrained coefficient. This follows because a reversal can be more likely, *ceteris paribus*, the stronger the direct correlation between the relevant domestic and foreign variables. Reexamination of the U.S.-German data over both the July 1974 to February 1978 and July 1974 to April 1980 periods using an unconstrained specification leads to conclusions very different from those of Dornbusch and Frankel. Our results show that earlier evidence offered in support of the monetary model, as well as recent evidence indicating its collapse, are the result of sign reversals induced by the subtractive linear constraints. Unconstrained estimates show that the model explains the mark-dollar exchange rate equally well before and after February 1978. Furthermore, our evidence tends to support the Chicago variant, which stresses the significance of secular rates of inflation, over *RID* and the Keynesian special case. Finally, inclusion of the current account does not significantly improve the explanatory power of the monetary model, but current account information may still be important.

I. Real Interest Rate Differential Model and Two Modifications

The *RID* model estimated by Frankel is

$$(1) \qquad e=c+\psi(m_1-m_2)-\phi(y_1-y_2)+\alpha(r_1-r_2)+\beta(\pi_1-\pi_2)$$

where e is the logarithm of the mark/dollar spot exchange rate; c a constant; m the logarithm of the money supply; y the logarithm of output; r the nominal interest rate; π the

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TABLE 1—REGRESSION ESTIMATES OF THE REAL INTEREST DIFFERENTIAL MODEL OF THE MARK-DOLLAR EXCHANGE RATE

Independent Variables	Regression A		Regression B		Regression C	
	7-74 to 2-78	7-74 to 4-80	7-74 to 2-78	7-74 to 4-80	7-74 to 2-78	7-74 to 4-80
Intercept	−3.42	−4.08	2.27	1.86	−6.47	−1.64
	(−24.98)	(−23.40)	(1.28)	(1.65)	(−6.48)	(−1.31)
(m_1-m_2)	0.58	−0.57			−0.04	−0.65
	(2.44)	(−1.89)			(−0.13)	(−1.90)
m_1			0.37	0.24		
			(1.62)	(0.84)		
m_2			−2.44	−1.84		
			(−4.84)	(−3.95)		
(y_1-y_2)	−0.26	0.02				
	(−1.14)	(0.08)				
y_1			−0.18	0.20	−0.35	−0.38
			(−0.85)	(0.77)	(−1.27)	(−1.23)
y_2			1.44	0.56	0.87	−0.13
			(7.25)	(2.20)	(3.86)	(−0.44)
(r_1-r_2)	−2.38	0.22				
	(−1.18)	(0.13)				
r_1			−5.99	0.02	−8.61	−7.28
			(−2.25)	(0.01)	(−2.44)	(−2.29)
r_2			−1.70	−2.50	−1.92	−1.95
			(−0.86)	(−1.29)	(0.72)	(−0.79)
$(\pi_1-\pi_2)$	21.58	13.33				
	(6.76)	(3.57)				
π_1			5.62	2.62	29.17	13.73
			(1.17)	(0.67)	(10.72)	(2.98)
π_2			0.05	3.53	−9.32	−9.04
			(0.01)	(0.75)	(−0.97)	(−1.66)
R^2	0.61	0.38	0.90	0.85	0.82	0.72
ρ	0.59	0.77	0.33	0.59	0.32	0.62

Note: Estimates are corrected for first-order autocorrelation (ρ) using Autoreg of the Statistical Analysis System; asymptotic t-statistics are in parenthesis below each coefficient. See the text for definition of variables; Frankel (1979) for data sources.

expected long-run inflation rate, which is proxied by the long-term government bond yield; and subscript one (two) refers to Germany (the United States). From the perspective of all monetary models of the exchange rate (including *RID*), coefficients ψ and ϕ are theoretically positive, implying that increases in German relative to U.S. money (income) increase (decrease) the mark price of the dollar. Frankel extends the standard monetary model by separating the interest rate effect into two terms: a real component (α negative) and an expected inflation term (β positive). He argues that Keynesian (Dornbusch, 1976) and Chicago (John Bilson and Jacob Frenkel) versions of the monetary approach are special cases of *RID*—the Keynesian model assumes that variations in the nominal interest rate differential are dominated by real forces, not changes in the expected inflation rate differential (α negative and β zero), and the Chicago model assumes equality between real interest rates, thus predicting that variations in the nominal interest differential are dominated by changes in the expected inflation rate differential (α positive and β zero if an inaccurate proxy for the expected inflation rate is used; α zero and β positive if an accurate proxy is used).

Regression estimates of equation (1) for the periods from July 1974 to February 1978 (Frankel's original sample) and from July 1974 to April 1980 based on the Cochrane-Orcutt procedure are summarized as regression A in Table 1. For the shorter period, all coefficients have signs supporting *RID*, with the first and last being significant, evidence

similar to that in Frankel (1979, p. 615).[1] For the longer sample, however, the coefficient of determination (R^2) falls, only the sign of the last coefficient supports *RID*, and the signs on relative money and relative income are inconsistent with all monetary models. Especially disturbing to the monetary approach is the fact that the sign on relative money is significantly negative rather than positive. This evidence from the longer sample is similar to estimates Dornbusch presented (1980, p. 150), and Frankel discussed (1980b, pp. 1–2).

In response to this apparent collapse of monetary models, Dornbusch and Frankel each offer modifications. Dornbusch (1980, pp. 152–63) specifies the current account as a significant determinant of the exchange rate within both rational expectations and portfolio balance models. Frankel (1980b, pp. 9–15) extends the money demand equation underlying *RID* to include a wealth proxy. In each study, the current account assumes a restored importance, and empirical evidence based upon data extended past February 1978 supports the modifications.

In the next two sections we demonstrate not only that the recent collapse of the monetary approach is illusory, hence that modifications may not be necessary, but also that previous estimates of the coefficient on relative money offered in support of the approach are spurious. The source of error in both instances is a sign reversal induced by constraining corresponding domestic and foreign variables to have equal but opposite effects on the exchange rate.

II. Linear Restrictions and Sign Reversals

Because each explanatory variable is specified in difference form, equation (1) restricts a given increase in each German variable to have the same effect on the spot exchange rate as an equivalent decrease in the corresponding U.S. variable. It is well known (see, for example, James Rasulo and D. Sykes Wilford) that linear restrictions in general yield biased parameter estimates. What is not well known, however, is that the type of bias resulting from *subtracting* variables is especially dangerous because, unlike the bias resulting from additive aggregation, it can lead to sign reversals when the variables are positively correlated.

Consider the simple equations (2) and (3), and assume (2) is the true model but (3) is estimated:

$$e=c+\psi_1 m_1+\psi_2 m_2+\mu \tag{2}$$

$$e=c+\psi(m_1-m_2)+\varepsilon \tag{3}$$

where e, c, m_1, and m_2 are defined as above; μ and ε are error terms; ψ_1 is positive; and ψ_2 is negative. Equation (3) constrains ψ_1 and $-\psi_2$ to be equal, implying that a given percentage increase in German money has the same effect on the spot rate as an equivalent percentage decrease in U.S. money. If ψ_1 does equal $-\psi_2$, then the expectation of $\hat{\psi}$ equals ψ_1 (and $-\psi_2$), where $\hat{\psi}$ is the least squares estimate of ψ from equation (3). If ψ_1 does not equal $-\psi_2$, however, the expectation of $\hat{\psi}$ does not equal ψ_1 (and $-\psi_2$), and may not even lie in the interval between ψ_1 and $-\psi_2$ if m_1 and m_2 are positively correlated. Thus, the expectation of $\hat{\psi}$ can differ in sign from ψ_1 and $-\psi_2$, implying that it is dangerous to infer the sign of ψ_1 and $-\psi_2$ in equation (2) from estimates of ψ in equation (3). Furthermore, such a sign difference can be more likely, *ceteris paribus*, the stronger the direct correlation between m_1 and m_2 (see the Appendix).[2]

Sign reversals of this type are not a problem when variables are added, for example, in aggregation. With direct correlation between the relevant variables, the expectation of the estimate of the constrained coefficient when the two variables are added (or averaged) does lie in the interval between the two

[1]The data analyzed in Table 1 were supplied by Frankel. Due to revisions of the data by Frankel, the estimate of regression A for the shorter sample is not identical to that in his 1979 article.

[2]For a theoretical analysis of sign reversals induced by subtractive linear constraints and additional evidence (regarding the response of trade to income), see our forthcoming paper. For a general discussion of the sign of restricted least squares estimates, see Edward Leamer (1975).

unconstrained parameters, hence cannot differ from their common sign.[3]

III. Reestimation of *RID*

The specification of equation (1) involves four linear constraints. Thus, there are four possible sources of specification bias, each of which could cause a sign reversal. Furthermore, bias in one coefficient in general biases all other coefficients, even if the other coefficients are not themselves a source of bias.

To determine the degree and severity of the bias involved in regression A estimates of equation (1), two less restrictive specifications are estimated: 1) an equation with all four explanatory variables in unconstrained form, that is, with separate German and U.S. variables; and 2) an equation with the last three variables in unconstrained form, but with German and U.S. money in difference form. The first modification removes all specification bias resulting from linear constraints, while the second removes all such bias except that resulting from the constraint on the coefficients on German and U.S. money.

Table 1 (regressions B and C) reports Cochrane-Orcutt estimates of these two modifications of equation (1) for both the shorter and longer samples. Estimates of the fully unconstrained equations (regression B) show markedly increased R^2s. Also, coefficients on money are of the correct sign and are relatively stable over the two samples, with the U.S. coefficient large relative to the German coefficient.[4] The coefficient on U.S. income remains significant in both samples, but the remaining coefficients are generally insignificant, perhaps due to multicollinearity. This evidence, unlike that based on regression A in Table 1, does not indicate serious structural change between the two samples.[5] Furthermore, t-tests for each pair of coefficients support a linear constraint only for the expected inflation rate variables (proxied by long-term government bond yields).

Estimates of the equations with only the money coefficients constrained (Table 1, regression C) show that the coefficient on relative money is negative rather than positive for both samples. This indicates that the positive and significant coefficient on relative money for the shorter sample in regression A spuriously results from the bias induced by the constraints on the other three pairs of coefficients.

Comparison of the estimates in Table 1 thus leads to the following conclusions. First, the positive and significant coefficient on relative money in regression A for the shorter sample (claimed by Frankel, 1979, and others to support the monetary approach) results from the bias from the other constrained coefficients; when this bias is removed, that is, when income, interest rates, and expected inflation proxies are specified with separate coefficients for the German and U.S. variables, the relative money coefficient turns negative (see regression C for the shorter sample). Second, this negative coefficient (which appears to refute the monetary approach) is itself a result of the bias involved in constraining the two money variables; when this second bias is also removed, that is, when all variables including money are specified with separate coefficients, the sign on German (U.S.) money becomes positive (negative), supporting the monetary approach (see regression B for the shorter sample). Third, the significant and negative coefficient on relative money in regression A for the longer sample (claimed by Dornbusch, 1980, and Frankel, 1980b, to refute the monetary approach) also reflects the bias

[3]Assume ψ_1 and ψ_2 in equation (2) are theoretically of the same sign, and that m_1 and m_2 in equation (3) are added. It follows (based on an analysis similar to that in the Appendix) that the expectation of $\hat{\psi}$ from the relevant constrained equation equals $w_1\psi_1+w_2\psi_2$, where w_1 is $[Var(m_1)+Cov(m_1, m_2)]/[Var(m_1)+Var(m_2)+2Cov(m_1, m_2)]$, and w_2 is $[Var(m_2)+Cov(m_1, m_2)]/[Var(m_1)+Var(m_2)+2Cov(m_1, m_2)]$. If $Cov(m_1, m_2)$ is positive, then w_1 and w_2 are positive, implying that the expectation of $\hat{\psi}$ is bounded by ψ_1 and ψ_2.

[4]The smaller German coefficient may result from sterilization activities by the German authorities.

[5]The appropriate F-test does reject the hypothesis of no structural change at the 5 percent level, but the coefficients on German and U.S. money are very similar for the two periods. The F-test for the equation involving an alternative measure of expected inflation (based on the *CPI*) reported in Section IV cannot reject the hypothesis of no structural change.

involved in constraining the explanatory variables; as with the shorter sample, when all variables are unconstrained, the signs of the coefficients on German and U.S. money become consistent with the monetary approach (see regression B for the longer sample).

To summarize, our evidence demonstrates that 1) earlier evidence based upon the sign of the coefficient on relative money, claimed to support the monetarist model, is spurious; 2) key evidence of the collapse of the model (i.e., a sign reversal on relative money) is also spurious; and 3) the source of error in both cases is the use of subtractive linear constraints.[6] Reestimation of *RID* after removing all constraints, however, suggests that no serious structural change has occurred moving from the shorter to the longer sample. Finally, estimation using Frankel's (1979) instrumental variable proxy for the expected inflation rate does not alter these findings.[7]

IV. Assessment of *RID* and Extensions

Two important questions remain: how does *RID* perform versus the Keynesian and Chicago special cases after the constraints are removed; and do the Dornbusch and Frankel modifications involving the current account further improve the model? The first question is difficult to answer because the coefficients on German and U.S. interest rates and expected inflation in Table 1 (those that discriminate the *RID*, Keynesian, and Chicago models) are generally insignificant, perhaps due to multicollinearity. In an attempt to reduce potential multicollinearity involving German and U.S. expected inflation rate proxies, we reestimate *RID* (in unconstrained form) using a twelve-month moving average of quarterly percentage changes in the consumer price index, rather than the long-term government bond yield.[8] These estimates (reported as regression D in Table 2) support the significance of the expected inflation variable for the longer sample, thereby refuting the Keynesian special case.[9] Also, the hypothesis of no structural change between the two periods now cannot be rejected at the 5 percent level of significance.

Table 2, regression E, reports estimates of the unconstrained exchange rate equation for both samples where the German and U.S. current accounts have been added. The inclusion of these accounts is similar to the incorporation of current account information both by Frankel (1980b) in his wealth proxy and by Dornbusch (1980) in his rational expectations and portfolio balance models.[10] From all these perspectives, increases in a country's current account are theoretically associated with an appreciation of its currency. In regression E for both samples, the two current account coefficients enter with the correct signs, and one of the two is significant. However, the appropriate F-test shows that the addition of the current account variables does not significantly improve the explanatory power of the equation.[11]

[6]Since there is little theoretical justification for invoking these constraints (except for m_1 and m_2 in the absence of sterilization), their use represents an attempt by researchers to increase the efficiency of coefficient estimates (by reducing multicollinearity) at the cost of (hopefully minimal) bias. As shown in the text, however, the use of subtractive linear constraints can result in substantial bias and sign reversals, hence is especially dangerous when the signs of coefficients are used to discriminate models. For this reason, the appropriateness of the restriction should be formally tested. One study which does test such constraints before imposing them is that by Kenneth Clements and Frenkel. For a general discussion regarding the use of prior information in regressions, see Leamer (1978, ch. 5).

[7]Another dramatic example of the danger of subtractive linear constraints is that the coefficient on relative money turns negative even for the shorter sample (-1.04 with a t-statistic of -4.35) in a fully constrained equation when the *CPI*-based expected inflation proxy is used. This occurs even though the coefficients on German and U.S. money in the unconstrained equation based on the *CPI* proxy (not reported here) are essentially identical to those based on the long-term government bond yield proxy (regression B for the shorter sample).

[8]This proxy is also used by Frankel (1980b).

[9]Consistent with Frankel's (1979) prediction, the expected inflation variable becomes more important when the sample includes a period of high inflation, i.e., the years 1978–80.

[10]The detailed theoretical analysis for the rational expectations approach is presented in Dornbusch and Stanley Fischer.

[11]Inclusion of the current account does reduce the coefficients on German and U.S. expected inflation variables in both samples, suggesting either that the current account and expected inflation are both important determinants or that they are causally linked.

TABLE 2—REGRESSION ESTIMATES OF EXTENSIONS OF THE *RID* MODEL OF THE MARK-DOLLAR EXCHANGE RATE

Independent Variables	Regression D		Regression E	
	July 1974-Feb. 1978	July 1974-April 1980	July 1974-Feb. 1978	July 1974-April 1980
Intercept	2.48	.54	−.90	3.65
	(1.73)	(.62)	(−.22)	(2.71)
m_1	.53	.02	.30	−.09
	(2.05)	(.08)	(1.13)	(−.36)
m_2	−2.60	−1.12	−1.42	−1.53
	(−6.28)	(−2.74)	(−2.47)	(−3.53)
y_1	−.06	.11	−.10	−.07
	(−.25)	(.49)	(−.48)	(−.34)
y_2	1.29	.32	.87	.64
	(5.34)	(1.45)	(3.21)	(3.11)
r_1	−2.44	2.11	.46	.17
	(−.82)	(.86)	(.16)	(.08)
r_2	−2.21	.85	.42	.69
	(−1.33)	(.69)	(.23)	(.61)
$\pi_1(CPI)$	8.72	10.72	.38	1.37
	(1.46)	(3.08)	(.06)	(.30)
$\pi_2(CPI)$	−2.33	−10.09	1.55	−5.26
	(−1.01)	(−5.11)	(.64)	(−2.51)
CA_1			−.23	−.24
			(−1.16)	(−3.96)
CA_2			.26	.07
			(2.27)	(1.20)
R^2	.91	.92	.93	.95
ρ	.32	.52	.29	.46

Note: π is a twelve-month moving average of quarterly percentage changes in the Consumer Price Index; CA the (logarithm) of the current account plus twice the largest negative value to convert to a positive index divided by the *CPI* over the previous year. Monthly CA data for the United States are obtained from quarterly data (Board of Governors) by within quarter interpolation using the U.S. trade balance. Monthly U.S. trade balance and German current account data are from OECD. See Table 1 for estimation procedure and description of other variables and data sources.

To summarize, estimates in Table 2 for the longer sample tend to support the Chicago variant of the monetarist model that stresses the significance of inflationary expectations. However, because of possible multicollinearity, significant autocorrelation in the ordinary least squares residuals, questions regarding the magnitudes of some coefficients (for example, on German and U.S. money), and the possible importance of the current account, further tests of *RID* and extensions, especially comparative tests of competing hypotheses, are warranted.

V. Conclusion

Empirical tests of the monetary model of exchange rate determination typically constrain the coefficients on corresponding domestic and foreign explanatory variables to have equal but opposite effects, a restriction generally invoked not for theoretical reasons but to reduce multicollinearity. Such estimates of the mark-dollar exchange rate support Frankel's real interest differential version of the model prior to early 1978, but suggest a collapse of all monetary models thereafter. In response to this collapse, Dornbusch and Frankel derive and estimate modifications involving the current account.

In this paper, we reestimate Frankel's monetary model of the mark-dollar exchange rate with unconstrained coefficients, and reach conclusions very different from those of Dornbusch and Frankel. Our results show that earlier evidence offered in support of the model, as well as recent evidence indicating its collapse, are the result of sign rever-

sals induced by subtractive linear constraints. Based on an unconstrained specification, our estimates 1) tend to support the Chicago variant of the model that stresses the significance of secular rates of inflation; 2) explain the mark-dollar exchange rate equally well before and after early 1978; and 3) suggest that inclusion of the current account does not significantly improve the explanatory power of the model, but that current account information may still play an important role.

Because many empirical studies of the monetary approach to the balance of payments/exchange rate (for example, those listed in Rasulo and Wilford and many of those surveyed by Mordechai Kreinin and Lawrence Officer) do impose subtractive linear constraints without formally testing them, the problem of sign reversals shown here to plague the Dornbusch and Frankel studies may well permeate this literature.

APPENDIX

It can be shown (following J. Johnston, pp. 157–159) that the ordinary least squares estimate of ψ from equation (3) is

$$(1') \qquad \hat{\psi}=w_1\hat{\psi}_1+w_2(-\hat{\psi}_2)$$

where w_1 is $[Var(m_1)-Cov(m_1, m_2)]/[Var(m_1)+Var(m_2)-2Cov(m_1, m_2)]$; w_2 is $[Var(m_2)-Cov(m_1, m_2)]/[Var(m_1)+Var(m_2)-2Cov(m_1,m_2)]$; w_1 plus w_2 equals one; and $\hat{\psi}_1$ and $\hat{\psi}_2$ are the unconstrained least squares estimates of ψ_1 and ψ_2, respectively. The expectation of equation (1′) is

$$(2') \qquad E[\hat{\psi}]=w_1\psi_1+w_2(-\psi_2).$$

If ψ_1 equals $-\psi_2$, then $E(\hat{\psi})$ equals ψ_1 (and also $-\psi_2$). If ψ_1 does not equal $-\psi_2$, and if m_1 and m_2 are uncorrelated or inversely correlated, the weights w_1 and w_2 are nonnegative, which implies that $E(\hat{\psi})$ is bounded by ψ_1 and $-\psi_2$. As a consequence, $E(\hat{\psi})$ and ψ_1 must have the same sign.

If m_1 and m_2 are directly correlated, however, either w_1 or w_2 may be negative. If the variances of m_1 and m_2 differ, then the stronger the direct correlation, *ceteris paribus*, the greater the probability that either w_1 or w_2 will be negative; with a direct correlation of one, w_1 or w_2 is unambiguously negative. A negative w_1 or w_2 implies that $E(\hat{\psi})$ is *not* bounded by ψ_1 and $-\psi_2$, and in fact may differ in sign from ψ_1 (and $-\psi_2$). A sign difference between $E(\hat{\psi})$ and ψ_1 requires (in addition to a negative w_1 or w_2) that 1) the negative weight be associated with the larger coefficient ψ_1 or ψ_2 (in absolute value), and 2) the product of the negative weight and its associated coefficient exceed (in absolute value) the product of the positive weight and its coefficient. Finally, from the definitions of w_1 and w_2, the negative weight is always associated with the money series which has the lesser variation.

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On the Mark: Comment

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Almost all recent research on exchange rate determination has conceived of the exchange rate as being a price that moves to equilibrate markets for stocks of financial assets. This approach contrasts sharply with older, traditional flow-market theories in which the exchange rate was assumed to equilibrate flow demands and supplies for foreign exchange. One attraction of the new asset-equilibrium approach is its purported ability to explain a wide variety of stylized facts concerning floating exchange rates.[1] Indeed, one class of asset-equilibrium models, usually called monetary models, because of their emphasis on the exchange rate's role in equilibrating money demand and supply, has been subjected to a number of seemingly successful tests.

In a recent provocative article in this *Review*, Jeffrey Frankel dichotomizes the monetary approach into two competing subgroups. One, called by Frankel the "Chicago" or Frenkel-Bilson approach, assumes that goods prices are perfectly flexible, thus ensuring the continuous maintenance of purchasing power parity. In an important paper, Jacob Frenkel tests this theory against hyperinflation data from the 1920's and claims that the data support the theory. John Bilson (1978, 1979) also has tested variants of this theory with more recent data and also has found that the empirical evidence supports the theory.

The second theory, dubbed "Keynesian" by Frankel, assumes some goods-price sluggishness, creating the possibility of temporary deviations of relative prices from purchasing power parity. In his paper, Frankel develops a version of this theory and tests it against recent deutsche mark-dollar data. On the basis of his tests, it appears that the data accord very favorably with his model. Furthermore, no empirical support is found for the Chicago or Frenkel-Bilson model.

Although these competing monetary models have very different assumptions about goods-price behavior, they both subscribe to John Muth's (1961) idea of rational expectations when they model expectations of the exchange rate. The empirical tests of these models, however, have not exploited or fully taken account of the econometric implications of this assumption.[2] Consequently, these tests have two distinct shortcomings. First, and perhaps most serious, the estimates of these models are not consistent; this occurs because the rationally expected exchange rate change, which is used as an explanatory variable in the estimated exchange rate equation, is correlated with the error term in that equation.[3]

Second, the tests do not exploit the fact that there are testable overidentifying restrictions imposed on the model by the rational expectations assumption. Such a test seems especially useful in light of the recent arguments by, among others, Benjamin Friedman, that rational expectations are at best long-run phenomenon.

In this comment, we develop the econometric framework that rectifies these shortcomings of existing tests of the monetary model. Using this framework, we show that Frankel's estimates of his monetary model are inconsistent. We then present consistent, efficient estimates of his model which fail to support his theory. Finally, we show that the overidentifying restrictions imposed on the model by the rational expectations assump-

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[1]See Michael Mussa on this point.

[2]Besides Frankel, Jacob Frenkel, Bilson (1978, 1979), and Kenneth Clements and Frenkel have tested monetary models.

[3]This result is similar to one developed by Thomas Sargent in his study of money demand and rational expectations in hyperinflation. It is also noted by Robert Hodrick.

tion are not satisfied by the data. While we concentrate on Frankel's model and tests, we should note that the tests apply as well to other monetary models.

In Section I we briefly develop a discrete-time, rational expectations analogue of the Frankel model. Our derivation highlights the critical importance to the model of implicit assumptions made by Frankel about the stochastic processes governing the behavior of the exogenous variables. We find that one of his key assumptions about money growth rates is not supported by the data. This derivation also permits us to point out the econometric problem with Frankel's empirical test of his model, and to describe how proper tests should be conducted. Section II presents our own implementation of these tests. Section III presents the summary and conclusions, emphasizing likely theoretical extensions of the monetary approach which should make it a more realistic description of economic reality.

I. The Model

Our purpose here is to develop from Frankel's model what Kenneth Wallis calls observable reduced-form equations. This permits us to show why the estimating equation used in his study leads to inconsistent estimates. We also derive the overidentifying cross-equation parameter restrictions which we use to test the Frankel model under rational expectations. For simplicity, and in keeping with Frankel and much of the other literature, we assume that both home and foreign countries have identical parameter values for all functional equations. Thus, most variables can be expressed as relative magnitudes, that is, as the ratio of the home country to the foreign country variable.

The main components of the Frankel model are a money-market equilibrium condition, an assumption of "uncovered" interest arbitrage, a slow goods-price adjustment scheme, and the rational expectations assumption. The money-market condition is

$$(1) \qquad m_t - p_t = \phi y_t - \lambda r_t + z_t;$$

where m is the *log* of relative money supplies, p the *log* of relative price level, y the *log* of relative real income levels, r the nominal interest differential, and z an error term which may be serially correlated. Both y_t and m_t are assumed exogenous. For expository ease, z_t will be assumed to be serially uncorrelated.

The assumption of uncovered interest arbitrage results from the twin assumptions of zero profits accruing to covered interest arbitrage and a zero-risk premium between foreign and domestic assets. Assuming rational expectations, the uncovered arbitrage condition is represented as

$$(2) \qquad r_t = E_t e_{t+1} - e_t,$$

where E_t is the conditional expectation operator.

The Frankel price-adjustment equation stipulates that relative price-*level* changes are a function of: (a) relative excess demands, where relative excess demands depend only on relative *prices*; and (b) the long-run expected inflation differential, π_t:

$$(3) \qquad p_{t+1} - p_t = \delta(e_t - p_t) + \pi_t + w_{t+1}.$$

This is identical to Frankel's price equation, except that it is in discrete time, and there is assumed to be a zero-mean, serially uncorrelated error term w_{t+1}. Following Frankel (p. 611), we think of π_t as long-run relative monetary growth rates that are known to the public. To complete the model, we need a description of the stochastic process governing the evolution of the exogenous variables m and y. To be consistent with what is an implicit assumption of Frankel,[4] we assume that y_t follows a random

$$(4) \qquad y_t = y_{t-1} + u_t,$$

and that m_t follows a random walk around a trend which also follows a random walk:

$$(5) \qquad m_t = m_{t-1} + \eta_t + \pi_t, \quad \pi_t = \pi_{t-1} + x_t,$$

where η_t, x_t, and u_t are zero-mean serially uncorrelated random variables.

[4]See Frankel, p. 613, fn. 7.

With these assumptions, the model can be solved, yielding the following reduced-form equations for e_t and r_t:[5]

$$(6)\quad e_t=(1-C_2)m_t+C_2p_t-\phi(1-C_2)y_t+\lambda(1-C_2)\pi_t-(1/\lambda)z_t/(1-C_2\delta);$$

$$(7)\quad r_t=E_te_{t+1}-e_t=(-1/\lambda)(m_t-p_t-\phi y_t-z_t);$$

where

$$(8)\quad C_2=\left[1-(1+4/\delta\lambda)^{1/2}\right]/2<0.$$

Equation (6) is the reduced-form exchange rate equation for the Frankel model under rational expectations. Note that the coefficient on m_t is greater than one; the exchange rate "overshoots" its long-run equilibrium value. Also note that the sum of coefficients on m_t and p_t is one; this reflects the long-run zero-degree homogeneity of the system with respect to nominal money-supply changes, that is, purchasing power parity holds in the long run.

For purposes of our critique of Frankel's econometric analysis, the most relevant point about (6) and (7) is that they show that r_t is obviously correlated with z_t. Frankel estimates the following equation;

$$(9)\quad e_t=m_t-\phi y_t-(1/\theta)r_t+(1/\theta+\lambda)\pi_t+z_t,$$

where θ is a parameter related to our C_2 (see the Appendix for the exact relationship). Consequently, his parameter estimates are inconsistent, since r_t is correlated with z_t.

To test Frankel's model under rational expectations, (6), (7), and (3) should be estimated simultaneously, subject to the six implied overidentifying within- and cross-equation parameter constraints. The system can then be estimated without these overidentifying constraints, and a likelihood ratio test used to test the constraints. Rewriting equations (3), (6), and (7) as follows:

$$(10)\quad p_t=A_0+A_1e_{t-1}+A_2p_{t-1}+A_3\pi_t,$$

$$(11)\quad r_t=B_0+B_1m_t+B_2p_t+B_3y_t,$$

$$(12)\quad e_t=C_0+C_1m_t+C_2p_t+C_3y_t+C_4\pi_t;$$

the six constraints can be expressed as equation (8) and

$$A_1+A_2=1;\quad C_1+C_2=1;\quad B_1+B_2=0;$$
$$-C_3/(1-C_2)=B_3/B_2;$$
$$C_4/(1-C_2)=1/B_2.$$

The next section of the paper presents the results from these and other tests of the Frankel model.

II. Econometric Results

Our econometric results are presented in three parts. The first shows results for regressions of the exogenous variables on lagged values of themselves. We thus test the assumptions implicit in Frankel's paper about the stochastic processes governing the exogenous variables.[6] For the most part, Frankel's assumptions are correct as can be seen in Table 1. The only exception is his assumption that relative money supply growth rates follow a random walk: evidence does not support this hypothesis. For this reason, we report results both with and without Frankel's expected long-run inflation differential proxy as an explanatory variable. As expected from the above results, all estimates of the coefficient on this explanatory variable turn out to be insignificant.

Single equation estimates of the three reduced-form equations (3), (6), and (7) are presented in Table 2. These estimates are consistent, and generally do not provide support for the model. For the exchange rate

[5]Details of the solution are in the Appendix.

[6]Frankel's model can be developed with alternative assumptions about the stochastic processes. This, however, would lead to different reduced forms.

TABLE 1—REGRESSIONS OF THE EXOGENOUS VARIABLES ON THEIR OWN PAST VALUES (July 1974–February 1978)

	Equation	R^2	D.W.
(1)	$m_t = -\underset{(.02)}{.108} + \underset{(.03)}{.96}\, m_{t-1}$	.96	2.25
(2)	$m_t = -\underset{(.02)}{.02} + \underset{(.16)}{.81}\, m_{t-1} + \underset{(.15)}{.14}\, m_{t-2}$	.96	2.02
(3)	$m_t = -\underset{(.02)}{.03} + \underset{(.16)}{.76}\, m_{t-1} - \underset{(.20)}{.08}\, m_{t-2} + \underset{(.16)}{.26}\, m_{t-3}$	.96	1.97
(4)	$y_t = -\underset{(.19)}{.28} + \underset{(.08)}{.89}\, y_{t-1}$	.76	1.82
(5)	$y_t = -\underset{(.19)}{.27} + \underset{(.17)}{.87}\, y_{t-1} + \underset{(.16)}{.02}\, y_{t-2}$	.76	1.78
(6)	$y_t = -\underset{(.20)}{.32} + \underset{(.17)}{.86}\, y_{t-1} + \underset{(.23)}{.19}\, y_{t-2} - \underset{(.17)}{.17}\, y_{t-3}$	.77	1.73
(7)	$\Delta m_t = \underset{(.001)}{.005} - \underset{(.15)}{.12}\, \Delta m_{t-1}$	.02	2.03

Note: Standard errors are reported in parentheses. Definitions: $m_t \equiv log$ (German M1/U.S.M1); $y_t \equiv log$ (German industrial prod./U.S. industrial prod.).
Source: The data is from Frankel.

equation, once the Cochrane-Orcutt correction is made, all variables are insignificant except for income, and the money-supply coefficient point estimate of (.37) is more than two standard deviations below one; the theory predicts it should be greater than one. This, of course, means that the sum of the coefficients on the money supply and the price level will not sum to one, as the theory predicts they should. In fact, they sum to −.29.

The Frankel exchange rate equation estimate without expected inflation as an explanatory variable is also presented in Table 2. The results do not change much; they are still not supportive of the theory. Again, there is not support for overshooting, since the m_t coefficient is only .32, which is more than two standard deviations below one, and the constraint imposed on the sum of the m_t and p_t coefficients is not satisfied (the sum is (−.25), while it should be 1).

For the price equation (equation (3)) while both the lagged price and lagged exchange rate coefficient estimates are of correct sign and significant, the expected inflation coefficient is insignificant. Also, the sum of the estimated lagged price and lagged exchange rate coefficients is significantly less than one. The estimated equation without expected inflation as an explanatory variable is also reported: the results are similar to those from the other equation.

Finally, for the interest rate equation, once the correction is made for high serial correlation, the results are not very supportive of the theory. In particular, the price coefficient has the wrong sign, and the income coefficient is insignificant.

On balance, none of the single equation estimation results support the theory. Another piece of evidence to corroborate this view is the full-information maximum-likelihood estimates of the system (3), (6), (7), and (8). The results are displayed in Table 3. Again, the parameter estimates are not supportive of the model; λ has the wrong sign and is *significant*, and C_2 is computed to be complex, whereas it should be negative.

The final test we apply to the Frankel model is a likelihood-ratio test of the significance of the overidentifying restrictions embodied in equation (3), (6), (7), and (8). To carry out this test, equations (9), (10), and (11) were estimated simultaneously with no parameter restrictions imposed. The *log* of the likelihood function from this estimation was 277.59. Twice the absolute value of the difference between the *log* of the likelihood functions from the two estimation procedures is distributed as *chi*-squared with five degrees of freedom. The actual value from this computation is 65.52. At the .005 significance level, the critical value is 16.75; the constraints imposed by the Frankel model under rational expectations are soundly rejected.[7]

[7]In our final estimations, we did not include π, the proxy for expected inflation, as an explanatory variable, since the results of Tables 1 and 2 suggested it was not appropriate.

TABLE 2—SINGLE EQUATION ESTIMATES
(July 1974–February 1978)

Technique	c	m_t	p_t	y_t	π_t	R^2	$D.W.$	Rho
The Frankel Exchange Rate Equation[a]								
OLS	−4.66	.80	1.92	−.70	.05	.81	.78	
	(−.51)	(.17)	(.82)	(−.19)	(.009)			
CORC	−4.75	.37	−.66	−.36	.014	.98	1.29	.98
	(.54)	(.27)	(−.88)	(−.19)	(.01)			(.03)
CORC	−4.80	.32	−.57	−.35		.91	1.16	.98
	(.54)	(.27)	(−.89)	(−.19)				(.03)
The Frankel Interest-Rate Equation[b]								
OLS	31.52	.90	12.16	12.38		.20	.52	
	(17.71)	(4.58)	(18.54)	(6.79)				
CORC	1.27	−23.11	−1.78	6.40		.71	2.10	.82
	(16.49)	(7.53)	(26.35)	(6.09)				(9.41)
The Frankel Price Equation[c]								
			p_{t-1}	e_{t-1}				
OLS	.08		.81	.03	.0006	.94	1.39	
	(.05)		(.09)	(.01)	(.0008)			
OLS	.09		.86	.03		.94	1.43	
	(.04)		(.05)	(.01)				

Note: Standard errors are in parentheses. The data is from Frankel.
[a]Dependent variable: e_t.
[b]Dependent variable: r_t, the German-U.S. interest differential.
[c]Dependent variable: p_t, the *log* of the German *CPI*/U.S. *CPI*.

TABLE 3—FULL-INFORMATION MAXIMUM-LIKELIHOOD ESTIMATES OF THE FRANKEL MODEL

Parameter	Estimated Value	Standard Error
δ	.04	.01
λ	−.06	.02
ϕ	.21	.14
Rho	1.01	.03
*Rho*1	.95	.07
$C2$ (computed)	Complex	

Note: *Rho*: First-order autoregressive parameter for the exchange rate equation. *Rho*1: First-order autoregressive parameter for the interest rate equation. Likelihood statistic: 65.52; Critical value $X_5^2(.005)=16.75$.

III. Summary and Conclusions

We have pointed out what we feel is an important econometric problem in existing tests of the monetary approach to the exchange rate, and have developed alternative testing methods which are free of this problem and also permit a direct test of the model under the rational expectations hypothesis. We use Frankel's data to implement our tests of his theory and find it not supported by the data.

We suggest that reasons for the failure of tests of the theory have to do with the array of simplifying assumptions employed by these models. Relaxation of these assumptions could involve developing a more complete picture of price adjustment, incorporating imperfect capital substitutability and mobility, or taking account of multicounty effects.

In addition, the choice of the deutsche mark-dollar exchange rate as a test of the monetary model presents special problems because of Germany's participation in various European fixed exchange rate schemes. These institutional arrangements, for one, make the German money supply endogenous rather than exogenous, and also bring to the forefront the modelling problems posed by a world of multilateral exchange rates.

In conclusion, we believe Frankel's monetary model gives important insights into exchange rate determination. In particular, his model is one of the first tested which relaxes the purchasing-power parity assumption. Nonetheless, it still appears to be unsuccessful as an empirical description of the recent history of the deutsche mark-dollar exchange rate. Furthermore, we suggest that future tests of exchange rate models which subscribe to the rational expectations hypothesis should proceed along the lines suggested in this paper. A rational expectations model which satisfies cross-equation overidentifying restrictions will have passed a strong test.

APPENDIX

To solve the model for reduced-form equations (6) and (7), first solve the money-market equilibrium condition for r_t, and substitute this into the uncovered interest arbitrage relationship. This yields

$$\text{(A1)} \quad e_t = E_t e_{t+1} + (1/\lambda)(m_t - p_t - \phi y_t - z_t).$$

Knowing that the final solution for e_t will have the form

$$\text{(A2)} \quad e_t = C_1 m_t + C_2 p_t + C_3 y_t + C_4 \pi_t + C_5 z_t,$$

we can determine $E_t e_{t+1}$:

$$\text{(A3)} \quad E_t e_{t+1} = C_1 E_t m_{t+1} + C_2 E_t p_{t+1} + C_3 E_t y_{t+1} + C_4 E_t \pi_{t+1}.$$

Using (3), (4), and (5), (A3) can be simplied to

$$\text{(A4)} \quad E_t e_{t+1} = C_1 m_t + C_2(1-\delta) p_t + C_2 \delta e_t + C_2 \pi_t + C_3 y_t + C_4 \pi_t + C_1 \pi_t.$$

Hence, (A1) reduces to

$$\text{(A5)} \quad e_t = (1/(1-C_2\delta))\big[m_t(1/\lambda + C_1) + y_t(C_3 + \phi/\lambda) + p_t(C_2(1-\delta) - 1/\lambda) + \pi_t(C_1 + C_2 + C_4) - z_t(1/\lambda)\big].$$

Since (A5) and (A2) must be consistent, the following restrictions on the C_2s must hold:

$$\text{(A6)} \quad C_1 = (1/\lambda + C_1)/(1 - C_2\delta);$$

$$\text{(A7)} \quad C_2 = (C_2(1-\delta) - (1/\lambda))/(1 - C_2\delta);$$

$$\text{(A8)} \quad C_3 = (C_3 + \phi/\lambda)/(1 - C_2\delta);$$

$$\text{(A9)} \quad C_4 = (C_1 + C_2 + C_4)/(1 - C_2\delta);$$

$$\text{(A10)} \quad C_5 = (-1/\lambda)/(1 - C_2\delta).$$

Equation (A7) is quadratic in C_2; the two roots of this equation are

$$\text{(A11)} \quad C_{2,1} = \left[1 + 1(1 + 4/\delta\lambda)^{1/2}\right]/2,$$
$$C_{2,2} = \left[1 - 1(1 + 4/\delta\lambda)^{1/2}\right]/2.$$

We can eliminate consideration of $C_{2,1}$ by requiring that the price equation (14) be stable. By stable, we mean that the price equation have some form of stationarity. Now, since the exogenous variables in our model are nonstationary, the *level* of prices will also be nonstationary. Since the first difference of our exogenous variables are stationary, the first difference of prices should be stationary under certain parameter restrictions. To see these restrictions, substitute (A2) into (3):

$$\text{(A12)} \quad p_{t+1} = (1 - \delta + C_2\delta) p_t + \delta C_1 m_t + \delta C_3 y_t + (\delta C_4 + 1)\pi_t + w_{t+1}.$$

Clearly, for the first difference of (A12) to have finite variance,

$$\text{(A13)} \quad |1 - \delta + C_2\delta| < 1$$

Now, if $C_{2,1}$ is the relevant root of (A7), this condition will not be satisfied, because $C_{2,1} > 1$. Hence, $C_{2,2} = C_2$ is the relevant root.

It is useful to compare our model with Frankel's. He develops his model by making the assumption that the expected exchange rate change is equal to the expected long-run inflation differential plus a fraction θ of the gap between the *log* of the long-run equilibrium exchange rate, e, and the *log* of the

current rate, e_t. Assuming uncovered interest arbitrage, this means that the following relationship between the interest differential, the expected inflation differential, and current and long-run exchange rate must hold:

$$r_t=\theta(\bar{e}_t-e_t)+\pi_t. \tag{A14}$$

Now, $\bar{e}_t$ is just that exchange rate expected to prevail in the long run; Frenkel (p. 612) shows it to be

$$\bar{e}_t=m_t-\phi y_t+\lambda\pi_t. \tag{A15}$$

By substituting (A15) into (A14), and rearranging, one obtains Frankel's estimating equation:

$$e_t=m_t-\phi y_t-(1/\theta)r_t+(1/\theta+\lambda)\pi_t. \tag{A16}$$

Now, if expectations are rational, θ will be a deterministic function of λ and δ. To determine this function, note that we can solve (1) for r_t and substitute into (A16) to obtain

$$\begin{aligned} e_t=&(1+1/\lambda\theta)m_t+(\phi^2/\lambda\theta)y_t \\ &-(1/\lambda\theta)p_t+(\lambda+1/\lambda\theta)\pi_t \\ &-(1/\lambda\theta)z_t. \end{aligned} \tag{A17}$$

Comparison of (A17) with (6) shows that for θ to be consistent with rational expectations

$$\theta=-1/\lambda C_2. \tag{A18}$$

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On the Mark: Reply

By JEFFREY A. FRANKEL*

The main analytical point of my 1979 paper was that a realistic monetary model of exchange rate determination must provide not only a role for secular monetary growth and inflation, as in the work of Jacob Frenkel (1976), Michael Mussa, and John Bilson, but also must take into account temporary deviations from purchasing power parity due to sticky prices, as in the work of Rudiger Dornbusch (1976, 1978). Most of the commentary on my 1979 paper has been focused not on this central theme, but rather on the empirical implementation of the model, and applies to the Frenkel-Bilson and Dornbusch variants as well as to my own. The motivation has partly been to explain why the equation, which fitted the mark-dollar data for the 1974–77 period so well, went awry in 1978. The dollar depreciated sharply against the mark in that year, although the money supply was increasing faster in Germany than in the United States, and the traditional determinants of money demand (especially real income) were increasing more slowly. In empirical studies through 1978 and 1979, only one of the four variables—relative money supply, relative real income, interest differential, and expected inflation differential—namely, the last, retained its sign and significance.[1]

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[1]The equation estimated appears as (A16) in the Appendix of Driskill and Sheffrin. The failure of the equation to explain the 1978 depreciation is documented by Dornbusch (1980), my 1980 paper, Lorenzo Bini Smaghi and Daniel Gros, Thomas Willett, and Waseem Khan.

I. The Return of the Real Interest Differential

Stephen Haynes and Joe Stone argue that the apparent breakdown of the monetary model is due to the imposition by most authors of the constraint that the money demand elasticities be the same in both countries and thus that all right-hand side variables enter in relative form (domestic relative to foreign) rather than separately. They point out that the imposition of such a constraint, if not justified, can lead to coefficient estimates that are not only biased but of incorrect sign. Thomas Willett also considers these constraints suspect. When they relax the constraints, Haynes and Stone find that the data continue to support the monetary model. But only the positive effect that expected inflation has on the exchange rate in the flexible-price version of Frenkel and Bilson is present, not the opposite effect which the interest rate has (for any given expected inflation rate) in the sticky-price version.

Robert Driskill and Steven Sheffrin argue that the nominal interest differential, which in the model is equal to the expected rate of depreciation, is endogenous. Richard Meese and Kenneth Rogoff perform causality tests and indeed reject the exogeneity of the interest rate in the equation. Thus single equation regressions with this variable on the right-hand side should produce biased estimates. Driskill and Sheffrin express the model in terms of three reduced-form equations that they estimate by single equation techniques. They also use full-information maximum likelihood (*FIML*) to estimate the system simultaneously, imposing the constraint that the expected speed of adjustment in the exchange rate equation is equal to the true speed of adjustment of the system. Russell Boyer and Robert Hodrick also suggest the latter technique. Driskill and Sheffrin obtain poor results using either technique.

The practice of putting the interest rate on the right-hand side of a regression is of course common, not only in exchange rate equations, but even more so in money-demand equations. In defense of this practice, it must be noted that it is at least possible that the interest rate is exogenous. One would probably have to argue that the central bank sets the interest rate on a monthly basis, so that random fluctuations in money demand are reflected in the money stock. This would not preclude the central bank from having targets for the money supply that it could succeed in hitting on a longer-term basis. Random short-term deviations of the actual money supply from the target, which are then generally corrected by the central bank in the following period, are a dominant current phenomenon in financial markets.

As I pointed out in my original paper, if it is money supplies that are endogenous, leaving them on the right-hand side of the equation produces inconsistent estimates of all coefficients. The easy solution is to impose the constraints of unit coefficients on the money supplies, constraints that one might wish to impose in any case for greater efficiency. When this is done, the relative money supply is in effect moved over to the left-hand side of the equation, and the estimates of the remaining variables become consistent. This strategy yielded results similar to those obtained from the unconstrained regression.

Still one must admit the possibility that it is the interest rate that is the endogenous variable in the money-demand function. More likely, *both* the money supply and the interest rate are endogenous variables. They respond, for example, to the monetary base, which is more directly under the control of the central bank.

In what could be interpreted as an attempt to deal with the possible endogeneity of the interest rates, Joseph Bisignano and Kevin Hoover argue that a superior specification is to replace these right-hand side variables with the ratio of the government bond supply to the monetary base. They obtain relatively favorable results for the Italian lire and Canadian dollar, but are less successful with the German mark and Japanese yen (all against the U.S. dollar). The strategy that would seem to be preferred would be to use the bond-monetary base ratio as an instrumental variable for the interest rate.

A number of authors have also been concerned that proxying the expected inflation variable by long-term interest rates or lagged actual inflation rates may introduce errors in variables, and that my instrumental variables technique may not be an adequate correction. Bisignano and Hoover try a measure of expected U.S. inflation based on the Livingston price expectations survey data. My own preference is simply to use the actual inflation rate for the preceding year. Willett experiments with other lag structures. But the choice of proxy does not seem to be crucial; the coefficient of the expected inflation rate is the one that has always appeared to be most robust with respect to sample period and estimation technique.

Table 1 reports an update of the estimation through the end of 1980. (Almost all the papers cited above use sample periods that end in 1978 or 1979.) The money-demand elasticities with respect to income and the expected inflation rate are not constrained to be the same in the two countries. I continue to impose the constraint that money supplies and interest rates appear in relative form, as it does not depend on the assumption of equal money demand elasticities.[2]

When we correct for serial correlation in regression 2, we find that not only are both of the expected inflation coefficients highly significant, but the coefficient of the interest differential rejoins the others in being significant and of the correct sign. One has only to read the newspapers to realize that the traditional Keynesian correlation between the value of the dollar and the interest differen-

[2]An appreciation of Haynes and Stone's point—that imposition of a constraint which may be untrue would bias the estimates—should not prevent us from imposing constraints such as homogeneity of the money supplies if we believe in them, a priori. Imposing the constraint that the interest rate coefficients are of equal magnitude implicitly assumes that the expected rate of depreciation continues to be governed by the same regressive form as before. When the parameters differ between the two countries, the expected rate of depreciation under perfect foresight becomes more complicated than this.

TABLE 1—ESTIMATION OF MONETARY EXCHANGE RATE EQUATION (14)
(Dependent Variable: *Log* OF MARK-DOLLAR RATE)

Sample	Technique	c	*gml-usmlb*	*gy*	*usy*	*gi-usi*	$g\Pi$	$us\Pi$	R^2	*D. W.*	$\hat{\rho}$
7401–8012	1. *OLSQ*	3.229	−.835[b]	−.885[a]	.289	−.190	4.717[a]	−3.932[a]	.93	.92	
		(.570)	(.158)	(.255)	(.195)	(.300)	(.813)	(.301)			
	2. *CORC*	3.283	−.770[b]	−.382	−.199	−.698[a]	3.485[a]	−3.444[a]		.95	.67
		(1.018)	(.268)	(.271)	(.240)	(.328)	(1.187)	(.539)			
7402–8011	3. *CORC*	−1.577	1.000	.049	.494	−.509	1.561	−.783	.97		.97
		(1.683)	(constrained)	(.261)	(.329)	(.314)	(1.409)	(.978)			
	4. *FAIR*	2.453	−.503	−.167	−.222	−1.465[a]	7.244[a]	−4.877[a]	.94		.66
		(1.217)	(.335)	(.319)	(.294)	(.516)	(2.081)	(.755)			
	5. *FAIR*	3.807	1.000	.137	−.667	−2.116[a]	11.310[a]	−5.102[a]	.95		.82
		(1.838)	(constrained)	(.391)	(.406)	(.649)	(3.091)	(1.320)			

Note: Definitions: *gml-usmlb*≡*log* of relative money supply, Germany/U.S. (M1B). *gy*, *usy*≡*log* of real income levels (proxied by industrial production), Germany and U.S. respectively. *gi-usi*≡nominal interest differential (short-term money market rates, per annum basis). $g\Pi$, $us\Pi$≡expected inflation rates (proxied by average *CPI* inflation over preceding twelve months). *OLSQ*: ordinary least squares; *CORC*: iterated Cochrane-Orcutt; *FAIR*: Fair's method of correcting for possible endogeneity of *gi-usi*, $g\Pi$ and $us\Pi$ (instrumental variables are the German and U.S. ratios of outstanding government bonds to monetary base, and the German and U.S. long-term government bond interest rates) in the presence of serial correlation (current and lagged values of all endogenous and included exogenous variables are added to the list of instruments).

[a]Significant at the 95 percent level and of the correct sign.

[b]Significant at the 95 percent level and of the incorrect sign.

tial strongly reemerged in the course of 1980: both peaked sharply in April and then again in December. The Federal Reserve Board can and does raise the real interest rate, and this does attract an incipient capital inflow that appreciates the dollar.

The coefficient of the relative money supply shows up highly significant but of incorrect sign, reflecting the rapid German monetary growth that was taking place during the period of dollar depreciation. The reason for the high rate of monetary growth was that the Bundesbank was intervening in an (unsuccessful) effort to prevent the mark from appreciating, and was failing to sterilize the effect of the reserve inflow. This type of reaction function provides another reason why the money supplies might be endogenous and why consistency might require that their coefficient be constrained to unity. When this constraint is imposed, and when we correct for serial correlation in regression 3, all coefficients lose their significance.

Recalling the arguments that the interest differential may be endogenous and that expected inflation rates may be measured with error, we make use of two sorts of instrumental variables: each country's bond-monetary base ratio for its interest rate, and the long-term interest differential for the expected inflation differential.[3] To correct for serial correlation and still insure consistent estimates, I adopt Fair's method of including among the instrumental variables, in addition to the current values of all exogenous variables, the lagged values of all endogenous and included exogenous variables. Regression 4 is very much like regression 2; the coefficients on the interest differential and expected inflation rates are all significant and correct in sign. But the important finding is that, unlike under the single equation estimation techniques, when we impose the constraint of a unit coefficient on the relative money supply in regression 5, the other three coefficients do not lose their significance. In fact they rise in significance enough that it

[3]The claim that the long-term interest rate reflects the expected inflation rate more closely than does the short-term interest rate follows from two propositions. (a) An increase in the expected inflation rate becomes built into the short-term interest rate, but only with the passage of time, for example because sticky prices imply that it takes time for the real money supply to fall. And (b) the long-term interest rate depends on the average of the expected future short-term interest rates.

even becomes possible to accept statistically the hypothesis that the expected inflation coefficients are greater in absolute value than the interest differential coefficient; the difference is an estimate of the semielasticity of money demand with respect to the interest rate. This leaves only the income levels appearing insignificant. Perhaps other proxies than industrial production, or new instrumental variables, would improve their showing.

If the results are this favorable when instrumental variables are used, why do Driskill and Sheffrin get such poor results when they estimate the reduced form? One possibility is the presence of the price level, a "noisy" variable, in each of their estimated equations. On the other hand, one might not wish to put too much weight on the latest econometric results in Table 1, in light of how sensitive to the sample period the results have been in the past. Meese and Rogoff find that structural models do a worse job of predicting exchange rates outside the sample period of estimation than time-series models, particularly than simple random walks. This discouraging finding holds even when the structural models perform well in-sample and even when they are allowed to use the actual post-sample values of the exogenous variables. (However among the structural models they do find that the sticky-price monetary equation outperforms the flexible-price equation.)

II. The Puzzling Behavior of Money Supplies

The point of Boyer and Hodrick is that the use of current observed money supplies and income levels in place of their respective equilibrium values is valid only if expected future paths of money supplies and income levels can be described by constant growth rates over their current levels. This is correct.[4]

Boyer and Hodrick work out the solution of the general case in which money supplies can follow an arbitrary process, as does Kenneth Rogoff. This is also the exercise that was performed earlier by Mussa for the flexible price case. But showing how the current spot rate depends on the discounted sum of an infinite number of expected future money supplies, while it may be a useful theoretical exercise, is of limited practical relevance. Fortunately, as Mussa concluded, "It is reasonable to assume that people have relatively little information about events far in the future, except possibly in the form of predictions of long-run average levels or rates of growth. This assumption eliminates all but a finite number of terms... " (pp. 242–43). He proceeded to model the money supply process as a simple random walk on levels and trends, the same specification that I have adopted, and one that could be called the "benchmark" monetary process.[5]

But Mussa also considered the possibility that the money supply is subject to transitory fluctuations: monthly deviations from the target, as discussed above, that are removed by the central bank within the subsequent several months. If transitory fluctuations are large, one way of obtaining a better measure of the current target money supply that belongs in the regression equation is to use distributed lags for the money supply variables. The hypothesis is that the sum of the coefficients is unity. S. Calliari and Francesco Giavazzi use distributed money supply lags for the lire-dollar rate and obtain results that are favorable to the monetary equation, though to the flexible-price version rather than my sticky-price version.

Note that the use of past values of the money supply or of other variables in the exchange rate equation does not violate the hypothesis of market efficiency. There exists a remarkably persistent confusion on this score. In a recent paper in this *Review*, Douglas Caves and Edgar Feige claimed that proponents of the monetary approach

> ... have failed to recognize that one of the consequences of an efficient foreign

[4]However, this does not mean that people at each point in time are unaware of the possibility of future changes in the monetary and income growth rates. It is merely necessary that these disturbances have expectation zero, i.e., that the variables follow "a random walk on levels and trends."

[5]See my 1982 paper. In addition to Mussa, Jacob Frenkel (1976) and John Bilson can be viewed as having assumed the benchmark money supply process for the flexible price case.

> exchange market is to eliminate the possibility of indirectly observing a systematic relationship [between] exchange rates and past supplies of national monies. If the foreign exchange market is efficient, all monetary effects on exchange rates will be contemporaneous. [p. 121]

But as is well known, market efficiency requires not that the change in the spot rate be independent of past variables such as money supplies, but only that the change in the spot rate *in excess of the expected change* (as reflected, for example, in the interest differential or forward discount) be independent of past variables. The monetary models are perfectly consistent with market efficiency.[6]

While Boyer and Hodrick would have the relative money supply follow a stochastic process more complex than the benchmark process, the random walk on levels and trends, Driskill and Sheffrin would have the relative money supply follow a stochastic process simpler than the benchmark. In their Table 1, they find the data to support the hypothesis of a random walk on levels alone, with only a constant trend. I suspect that the denizens of financial markets who avidly scrutinize Federal Reserve Board reports for every sign of a change in the target monetary growth rate would be surprised to hear that it is constant (at least relative to the German rate). I suspect that they would be even more surprised to hear that the growth rate, relative to Germany, has been a *negative* constant. Even if one does not agree that the relative target money growth rate has been constant, it is undeniably true that U.S. monetary growth has on average been slower than German monetary growth for the 1974–78 period. In either case, the important variable for the model ultimately is not the monetary growth differential but the long-term inflation differential, which by any proxy has been both variable and positive.

[6]The mistake of thinking that efficiency in the foreign exchange market requires the spot rate to follow a random walk, and specifically that it precludes Dornbusch overshooting, is very common. It would undoubtedly be naive to hope that the confusion will end here.

The fact that for some time now U.S. monetary growth has been lower than inflation, let alone that it has been lower than the growth in nominal *GNP*, that is, that velocity has been rising, is a problem for macroeconomists in general (though for monetarists in particular). A large downward shift in the U.S. money demand equation beginning after 1973 has been widely noted, under the name "the mystery of the missing money" (see Stephen Goldfeld). Table 2 reports regressions of the U.S. real money supply against income and the interest rate on a sample from January 1974 to April 1980. The negative coefficient on the time trend shows that the downward shift has continued throughout the floating rate period, at an estimated rate of .3 percent per month.

Many solutions to the mystery of the missing money have been proposed. A majority can perhaps be subsumed under the following story. The unprecedented increase in inflation rates and interest rates that occurred in 1974, in the United States and throughout the world, induced innovations by individuals, firms, banks, and regulators to allow economizing on cash balances, to an extent not reflected in the old interest elasticity coefficient.[7] However, the phenomenon remains something of a mystery.

Less frequently noted is the fact that there has been an even stronger *upward* shift in German money demand. The highly significant positive coefficient on the time trend in Table 2 shows that the supply of marks has been increasing at a rate more than .4 percent a month faster than can be explained by the standard determinants of money demand. Thus there is a "mystery of the multiplying marks" in addition to that of the missing dollars. If the high (by historical standards) inflation rates and interest rates that have occurred in Germany since 1973 have induced financial innovation similar to that in the United States, it only compounds

[7]One version of the argument is that these innovations have taken the form of shifts into interest-paying money substitutes that should really be counted as money. Note, however, that including interest-paying checking accounts is not sufficient; they are included in M1B, on which the regressions reported in this paper are based.

TABLE 2—MONEY DEMAND EQUATIONS: *Log* OF REAL MONEY STOCK, JANUARY 1974–APRIL 1980

	Technique	Constant	*Log* of Income	Interest Rate	Time Trend	R^2	*D. W.*	$\hat{\rho}$
United States	*OLS*	−1.581[b]	.461[b]	−.0023[b]	−.0025[b]	.79	.26	
		(.208)	(.044)	(.0006)	(.0002)			
	CORC	−.034	.151[b]	.0005	−.0031[a]	.96		.99
		(.340)	(.066)	(.0006)	(.0017)			
Germany	*OLS*	−.449	.124	−.0074[b]	.0043[b]	.97	.30	
		(.446)	(.097)	(.0013)	(.0027)			
	CORC	.746[b]	−.138	−.0037	.0046[b]	.99		.93
		(.362)	(.079)	(.0024)	(.0008)			

Note: Standard errors are reported in parentheses.
[a]Significant at the 90 percent level.
[b]Significant at the 95 percent level.

the mystery of why the demand for marks has increased.

Whatever the explanations for the mysteries of the missing dollars and the multiplying marks, it seems unavoidable that they also constitute the explanation for the difficulties that the monetary models had in 1978, and for the negative coefficient that the relative money supply still has in Table 1 when unconstrained.

III. The Current Account Attempts a Comeback

The sharp decline of the dollar in 1978 coincided with a very large U.S. current account deficit. This fact has impelled many authors to turn to models that give a role to the current account, or more usually its accumulation. Most popular are the portfolio balance models of exchange rate determination that were originated by William Branson and Pentti Kouri. In contrast to the monetary models, they assumed that domestic and foreign bonds were imperfect substitutes. Thus a current account surplus, which is an increase in domestic wealth, led to an increase in demand for domestic bonds and an appreciation of the domestic currency.[8]

Peter Hooper and John Morton, Peter Isard, and I (1982) have each proposed models that, in similar ways, integrate the variant of the monetary equation based on real interest differentials with the portfolio balance models. We simply introduce a risk premium, defined as the interest differential less expected depreciation, where the monetary model previously assumed this equal to zero by uncovered interest parity. The risk premium is assumed related to the relative supply of domestic and foreign bonds, which then appears as a right-hand side variable along with the interest differential and expected inflation differential.

Cumulated current accounts tend to show up highly significant in all recent studies. However, a proper empirical implementation of the portfolio balance models would subtract the intervention by foreign central banks in support of the dollar from the supply of dollar assets (in addition to adding such intervention to the supply of foreign assets). When this is done, the models fail to explain the depreciation of the dollar.[9] The reason is that this intervention was more than double the U.S. current account deficit cumulated during 1977 and 1978, as pointed out by Hooper and Morton.

Lorenzo Bini Smaghi and Daniel Gros, at the suggestion of Robert Mundell, add the dollar price of gold to the other variables in

[8]Among the many authors counseling an abandonment of the monetary models in favor of the portfolio balance models are Driskill and Sheffrin. For general surveys of the two classes of models, see Dornbusch (1980) and my 1982 paper.

[9]See my 1982 paper.

my equation for the mark-dollar rate, and claim greatly improved results. They apparently have a portfolio balance model in mind, with the price of gold as a proxy for German gold holdings.

Several authors have developed models in which domestic financial wealth, and thus the cumulated current account, matter for reasons *other* than imperfect substitutability between domestic and foreign bonds.[10] Sterilized foreign exchange intervention does not matter in these models; as a result they are more likely to be able to explain the 1978 depreciation. One way in which to introduce domestic financial wealth is as a variable in the demand for money; real wealths simply join real incomes and interest rates as explanatory variables. Then the U.S. current account deficit might be able to explain not only the 1978 depreciation of the dollar, but the observed downward shift in the U.S. money-demand equation and the contemporaneous upward shift in the German money-demand equation as well.[11]

[10]Dornbusch (1980) discusses the possibilities. His favorite way in which to introduce the cumulated current account without imperfect substitutability is to assume that wealth is a determinant of domestic expenditure and income.

[11]This argument is made in my 1980 paper.

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Subsidy-Free Prices and Anonymous Equity

By GERALD R. FAULHABER AND STEPHEN B. LEVINSON*

In a recent article, Faulhaber offered a definition and analysis of cross-subsidization in public enterprise pricing: If at the stated prices, the provision of a commodity (or group of commodities) by a multicommodity profit-constrained enterprise leads to prices for the other commodities no higher than they would pay by themselves, then these prices are *subsidy-free* (1975, p. 966). The multicommodity pricing problem was cast as a cooperative game, in which subsidy-free prices (according to the above definition) corresponded to the "core" of the game: prices such that the revenues of each commodity (or subset of commodities) are no greater than the "stand-alone" cost of providing the commodity (or subset of commodities), and are no less than the incremental cost of that commodity (or subset).[1]

The analysis focused on subsidies between and among *commodities*; however, much of the interest of regulators and others concerned with public enterprise pricing has to do with subsidies between and among *consumer groups*. Are commercial and industrial users subsidizing (or being subsidized by) residential users? Are rural users subsidizers of urban users (or vice versa)? In Robert Willig's article, the absence of consumer subsidies is defined as anonymous equity in public enterprise pricing (a concept we sharpen, below).

The purpose of this paper is to explore the relationships between the concept of subsidy-free by commodity[2] and that of anonymous equity. Surprisingly, we find there are circumstances in which prices that are subsidy-free violate anonymous equity. However, we find that if the average incremental cost of each subset of commodities is declining, then prices are anonymously equitable if they are subsidy-free. This result is closely related to Proposition 2 in John Panzar and Willig. Lastly, we examine conditions on the underlying production technology which ensure that anonymous equity can be achieved. We draw on results in William Sharkey and Lester Telser.

I. The Model

We utilize a similar analytic framework to Faulhaber (1975); a regulated firm provides a set of commodities $N=\{1,2,\ldots,n\}$, with price and output vectors $p=(p_1,\ldots,p_n)$ and $Q=(Q_1,\ldots,Q_n)$, and a technology described by a multicommodity cost function $C(Q)$. We presume that the monopoly has a cost advantage in production, characterized by the subadditivity of the cost function C; that is, for any set of vectors $Q^1,\ldots,Q^k$

$$C\left(\sum_{j=1}^{k} Q^j\right) < \sum_{j=1}^{k} C(Q^j)$$

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[1]In later work by Faulhaber (1979), this "cost game" was shown to be an approximation to the correct Pareto-superiority analysis. If demands are independent, then prices which lead to revenues in the core of the cost game insure that provision of any commodity or subsets of commodities leads to prices for the other commodities no higher than they would otherwise be. With interdependent demands, the conditions under which provision of each subset of commodities is Pareto superior to nonprovision are somewhat more complex. For the purposes of this paper, it is sufficient to note that if the services in question are weak gross substitutes, then a necessary condition that prices be subsidy-free is that the resulting revenues lie in the core of the cost game.

[2]If a commodity includes a number of discrete cost items bundled together, or includes some form of rate averaging among high intensity and low intensity users (for example, flat rate local telephone service, or directory assistance), the potential for cross-subsidy may exist within the commodity. While this problem is of practical importance, we shall assume throughout the remainder of the paper that all such problems have been

over the relevant range. In other words, a single production entity can produce an output vector more cheaply than several such entities. We also assume that the firm's regulators have established prices such that the firm earns just the market return on capital,[3] that is,

$$(1) \qquad p \cdot Q(p) = C(Q).$$

This revenue requirement equation is satisfied by many price vectors; in Faulhaber (1975), the subset of price vectors which are subsidy-free are those which lead to revenues for each subset of commodities no greater than the stand-alone cost for that subset. Suppose $S \subseteq N$ is any subset of N, and p_S, Q_S denote the restriction of the price and quantity vectors to the set of commodities in S; then a price vector p is subsidy-free if and only if it satisfies (1) and

$$(2) \quad p_S \cdot Q_S(p) \leq C(Q_S), \quad \text{for all } S \subseteq N.$$

Combining (1) and (2), it is easy to see that revenues for all subsets of commodities must be no less than incremental costs;

$$(3) \quad p_T \cdot Q_T(p) \geq C(Q) - C(Q_{N-T}), \quad \text{for all } T \subseteq N.$$

The intuition concerning why (2) (or (3)) is a sensible cross-subsidy criterion is quite clear: if (2) is violated for some subset $S \subseteq N$, then the consumers of that subset could provide for their own demands at a cost $C(Q_S)$, charge themselves slightly lower prices (by continuity of the profit function), and have a profitable business. Thus, at stated prices, the consumers of S are paying higher prices than they otherwise would be paying; thereby providing a subsidy to the consumers of the services[4] in $N-S$.

However, it may be the case that the same consumers who consume commodities in S also consume commodities in $N-S$. If the S commodities are subsidizing the $N-S$ commodities, what can be said about individual consumers or groups of consumers? Let $M = \{1,2,\ldots,m\}$ be the set of consumers, and let $Q^j(p)$ be consumer j's demand vector of commodities produced by the regulated firm. If $V \subseteq M$ is any subset of consumers, we define $Q^V(p) \equiv \Sigma_{j \in V} Q^j(p)$. We define the price vector p to be *consumer subsidy-free* if (1) is satisfied and

$$(4) \quad p \cdot Q^V(p) \leq C(Q^V(p)), \quad \text{for all } V \subseteq M.$$

As before, we can combine (1) and (4) to obtain

$$(5) \quad p \cdot Q^W(p) \geq C(Q(p)) - C(Q^{(M-W)}(p)), \quad \text{for all } W \subseteq M.$$

The interpretation of (4) and (5) is identical to that of (2) and (3), except the quantity vectors are not projections onto the commodities axes, but rather aggregates of individual consumer demands.

In general, the relationship between subsidy-free prices and consumer subsidy-free prices depends critically on differences in demand patterns across consumers. The following propositions illustrate this quite forcefully; if consumers have identical demand patterns (up to a scale factor), then all prices are consumer subsidy free, even those involving subsidies among services. On the other hand, if consumers tend to "specialize" in consuming only certain commodities and not others, then subsidies among services can lead to nonequitable prices.

dealt with, and that the commodities are so defined that any consumer's per unit demand for the commodities imposes the same marginal cost on the firm as any other consumer's per unit demand.

[3]We further assume that the firm produces any output vector at least cost, and the price vector established is undominated, i.e., there is no other price vector less than or equal to the established price vector in all components which yields nonnegative returns. We do not thereby assert that achieving least cost production with undominated zero-economic-profit prices is easy in regulated enterprises. However, it is not the problem to which this paper is addressed.

[4]The potential this creates for competitive entry is hinted at in Faulhaber (1975) and thoroughly explored in the several articles that constitute the sustainability literature, principally William Baumol, Elizabeth Bailey, and Willig, and Panzar and Willig. In this paper, the equilibrium aspects of the problem are not considered.

PROPOSITION 1: *If the demand vectors of all consumers are proportional to each other (and thus to the market demand vector) and $C(\cdot)$ exhibits increasing returns to scale, then any price vector which leads to zero profit is consumer subsidy free whether subsidy-free or not.*

PROOF:

By hypothesis, $Q^j=\alpha^j Q$, α^j a scalar, for all $j\in M$, so that

$$Q^W=\left(\sum_{j\in W}\alpha^j\right)Q=\alpha^W Q \quad \text{for all } W\subseteq M.$$

Since $p\cdot Q=C(Q)$ and $C(\cdot)$ exhibits increasing returns to scale (both by hypothesis), we have, for all $W\subseteq M$, $p\cdot Q^W=\alpha^W p\cdot Q=\alpha^W C(Q)<C(\alpha^W Q)=C(Q^W)$.

PROPOSITION 2: *If* (a) $C(Q)=c\cdot Q+F$, *that is, fixed cost F plus constant marginal costs, and* (b) $W(i)=\{j\in M|Q_i^j>0$ *and* $Q_{N-i}^j=0\}$ *is nonempty, for all* $i\in N$ *(i.e., the set of consumers who demand commodity i and only commodity i is nonempty) then p is consumer subsidy-free if and only if p is subsidy-free.*

PROOF:

If p is subsidy-free, then $(p_i-c_i)Q_i\geqslant 0$ for all $i\in N$. Then for any $\alpha=(\alpha_1,\ldots,\alpha_n)$ with $0\leqslant\alpha_i\leqslant 1$, $\alpha\cdot(p-c)\cdot Q\geqslant 0$. For any $W\subseteq M$, let $\alpha_i^W=\Sigma_{j\in W}(Q_i^j/Q_i)$; then $\alpha^W\cdot(p-c)\cdot Q=(p-c)\cdot Q^W\geqslant 0$, for all $W\subseteq M$. Hence, p is consumer subsidy-free.

If p is not subsidy-free, then for some $S\subseteq N$, $(p_i-c_i)Q_i<0$, for all $i\in S$. Consider the set $W(S)=\cup_{i\in S}W(i)$, which is nonempty; since $Q_{N-S}^{W(S)}=0$ by definition of $W(S)$, $(p-c)\cdot Q^{W(S)}=(p_S-c_S)Q_S^{W(S)}$.

For $\alpha^{W(S)}>0$ and $(p_i-c_i)Q_i<0$ for all $i\in S$, we have that $\alpha^{W(S)}\cdot(p_S-c_S)\cdot Q_S<0$; thus, $W(S)$ is paying less than incremental cost and p is not consumer subsidy-free.

These two propositions show that the relationship between subsidy-free prices and consumer subsidy-free prices depends critically upon the actual pattern of individuals' demands. If individuals have proportional demand patterns, then the two concepts bear no relation to one another; if individuals have specialized demand patterns, then (at least for the simplest case of subadditive costs), the two concepts are identical.

In practice, we may expect to know little of individual consumer demands $Q^j(p)$, other than that their sum over all (some) consumers is equal to (less than) the observed market demand vector $Q(p)$. Therefore, an equity concept relative to a specific set of unobservable consumer demands is of little interest. A more restrictive approach that does not depend upon observing customer demands is to require that any conceivable set of consumer demand vectors generates revenues no greater than its stand-alone costs. Thus, if we consider any arbitrary vector $q=(q_1,\ldots,q_n)$, such that $q\leqslant Q(p)$, then it is possible that there is some subset V of actual consumers such that $q=Q^V(p)$. If every $q\leqslant Q(p)$ generates revenues no greater than stand-alone costs, then no possible consumer group could be paying more than it otherwise would. Formally, the price vector p is *anonymously equitable* if (1) is satisfied and

$$(6)\qquad p\cdot q\leqslant C(q),\quad \text{for all } q\leqslant Q(p);$$

and as before

$$(7)\qquad p\cdot q'\geqslant C(Q)-C(Q-q'),\qquad \text{for all } q'\leqslant Q(p).$$

If p is anonymously equitable, then it is consumer subsidy-free for any demand pattern $Q^j(p)$ for which $\Sigma_{j\in M}Q^j(p)=Q(p)$. We can now state the results of the paper.

PROPOSITION 3: *If the price vector p is anonymously equitable, then prices are no lower than marginal costs.*

PROOF:

Define $Q-\Delta^i=(Q_1,\ldots,Q_{i-1},Q_i-\Delta,Q_{i+1},\ldots,Q_n)$, for $\Delta>0$. Anonymous equity requires $p\cdot(Q-\Delta^i)\leqslant C(Q-\Delta^i)$. Since $p\cdot Q=C(Q)$, we have $p_i\Delta\geqslant C(Q)-C(Q-\Delta^i)$ or $p_i\geqslant[C(Q)-C(Q-\Delta^i)]/\Delta$. Letting $\Delta\to 0$, $p_i\geqslant\partial C(Q)/\partial Q_i$.

This result is related to Condition 6 in Panzar and Willig, as well as Proposition 3 in Sharkey and Telser.

PROPOSITION 4: *If the price vector p is anonymously equitable, then it is subsidy-free.*

PROOF:

For any $S \subseteq N$, let $q = Q_S(p) \leq Q(p)$. From (6), $p \cdot q \leq C(q)$, so that $p_S \cdot Q_S(p) \leq C(Q_S(p))$, and (2) is satisfied for all $S \subseteq N$.

Note: A possible set of consumers is one which consumes only services in S, while the other consumers consume nothing of the S commodities.

PROPOSITION 5: *A price vector which is subsidy-free need not be anonymously equitable.*

PROOF:

A counterexample is developed in Section III below.

Definition: The cost function exhibits declining average incremental cost (*DAIC*)[5] if

$$(8)\quad C(Q_S, Q_T) - C(Q_S) < \frac{C(Q_S, \lambda Q_T) - C(Q_S)}{\lambda} \quad \text{for } 0<\lambda<1;$$

$$S, T \subseteq N, S \cap T = \Phi, Q_T \neq 0.$$

Definition: A twice differentiable cost function exhibits weak cost complementarities (*WCC*) if $\partial^2 C / \partial Q_i \partial Q_j \leq 0$.

LEMMA: *If the cost function exhibits either declining average incremental cost or weak cost complementarities, then marginal cost pricing of the commodities in the set T will at most just cover the incremental cost of T, i.e.,*

$$(9)\quad \sum_{i \in T} Q_i \cdot C_i(Q_S, Q_T) - [C(Q_S, Q_T) - C(Q_S)] \leq 0;$$

$$S, T \subseteq N, S \cap T = \Phi.$$

PROOF:

Assume *DAIC* obtains; we know that the right-hand side of (8) is a decreasing function of λ in a neighborhood of $\lambda = 1$. Thus, *DAIC* implies that its derivative with respect to λ, evaluated at $\lambda = 1$, is nonpositive, or the desired result:

$$0 \geq \frac{d}{d\lambda}\left[\frac{C(Q_S, \lambda Q_T) - C(Q_S)}{\lambda}\right] = \sum_{i \in T} Q_i \cdot C_i(Q_S, Q_T) - [C(Q_S, Q_T) - C(Q_S)].$$

Assume that *WCC* obtains; then for all $0 \leq q_T \leq Q_T \cdot i \in T$

$$C_i(Q_S, Q_T) - C_i(Q_S, q_T) = \int_\Delta \sum_{i \in T} C_{ij}(Q_S, Y_T)\, dy_i \leq 0,$$

for Δ a smooth arc from q_T to Q_T. Rewriting incremental cost, we have

$$C(Q_S, Q_T) - C(Q_S) = \int_\Gamma \sum_{i \in T} C_i(Q_S, q_T)\, dq_i \geq \sum_{i \in T} \int_\Gamma C_i(Q_S, Q_T)\, dq_i = \sum_{i \in T} Q_i \cdot C_i(Q_S, Q_T),$$

for Γ a smooth arc from 0 to Q_T, the desired result.

PROPOSITION 6: *If the cost function exhibits either declining average incremental cost or weak cost complementarities, then all prices*

[5]This concept was introduced in Panzar and Willig, p. 11, where they noted that *DAIC* implies global nondecreasing returns to scale, as well as single product declining average cost. It is therefore a strong multiproduct generalization of the simple single product declining average cost.

which are subsidy free are anonymously equitable.

PROOF:

We show that if prices p are subsidy free and either *DAIC* or *WCC* obtains, then the maximum of revenues less stand-alone costs over all demand patterns no greater than market demands is negative.

$$\underset{q}{Max}\ p\cdot q-C(q) \text{ subject to } q\leqslant Q(p).$$

The Lagrangian is

$$(10)\quad L=p\cdot q-C(q)+\sum_{i=1}^{n}\lambda_i(Q_i(p)-q_i).$$

$$\frac{\partial L}{\partial q_i}=p_i-C_i(q)-\lambda_i\leqslant 0,$$

$$q_i[p_i-C_i(q)-\lambda_i]=0;$$

$$\frac{\partial L}{\partial \lambda_i}=Q_i(p)-q_i\geqslant 0,\ \lambda_i[Q_i(p)-q_i]=0.$$

Let S be the set of commodities for which $0<q_i<Q_i(p)$. Then $\lambda_i=0$ for all $i\in S$. Substituting into (10) yields $p_i=C_i(q)$, for all $i\in S$. That is, q is adjusted so that at the stated prices, marginal cost pricing obtains for all commodities in S. Then

$$p\cdot q-C(q)=\sum_{i\in N-S}p_iQ_i(p)+\sum_{j\in S}q_jC_j(q_S,Q_{N-S})-C(Q_S,Q_{N-S}).$$

Adding and subtracting $C(Q_{N-S})$, and rearranging terms, we obtain

$$(11)\quad p\cdot q-C(q)=\left[\sum_{i\in N-S}p_iQ_i(p)-C(Q_{N-S})\right]+\left[\sum_{j\in S}q_jC_j(q_S,Q_{N-S})-(C(q_S,Q_{N-S})-C(Q_{N-S}))\right].$$

The first term in (11) is nonpositive since p is subsidy free; the second-term is nonpositive by the lemma (inequality (9)), since the cost function exhibits either *DAIC* or *WCC*. Hence, for all $q<Q(p)$, $p\cdot q-C(q)\leqslant 0$ and the price vector is therefore anonymously equitable.

Proposition 6 thus provides a sufficient condition for subsidy-free prices to be anonymously equitable. In the next section, we show that even in rather everyday circumstances, we cannot expect this correspondence to be maintained.

II. Anonymous Equity vs. Subsidy-Free Prices

In this section we use a simple peak load pricing example to illustrate the distinction between subsidy-free pricing by commodity (i.e., by time of day) and anonymously equitable pricing.

We assume: 1) the firm faces a load curve as in Figure 1, which has two times of day. Period 1 is distinctly the peak period, and Period 2 is distinctly the off-peak period (i.e., no joint peak); 2) the firm supplies a commodity with fixed proportions, constant returns to scale production function as in Peter Steiner; 3) the firm is regulated to earn no more than a fair return (zero economic profits); 4) interperiod demands are independent.

By the first assumption, $Q_1>Q_2$. By the second assumption, we have constant mar-

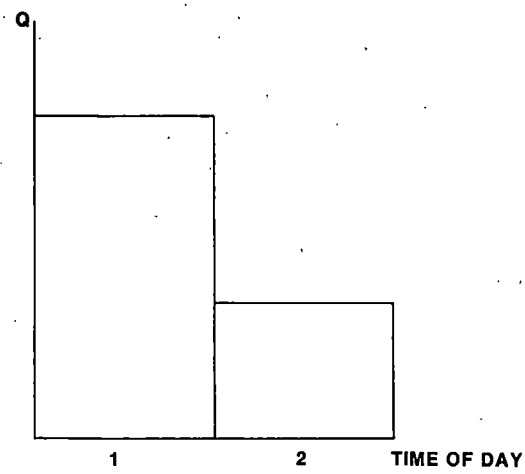

FIGURE 1.

ginal operating cost b per unit of demand and constant marginal capacity cost β per unit of peak demand. By the third assumption, the zero-profit constraint takes the form

$$(12)\quad P_1Q_1+P_2Q_2=\beta Q_1+b(Q_1+Q_2) =C(Q_1,Q_2),$$

where $C(Q_1,Q_2)$ is the cost of producing Q_1 and Q_2 jointly. By the fourth assumption, $\partial Q_2/\partial P_1=\partial Q_1/\partial P_2=0$.

In order to obtain prices which are anonymously equitable, we must demonstrate that if any arbitrary set of consumers were eliminated, then the remaining set would be no better off by being able to cover lower total cost.

Let X be any arbitrary set of consumers and let Y be its complement. Then we eliminate the demands represented by X and check the impact on consumers in Y. Upon elimination of X, total revenue, TR, for the firm will change by

$$(13)\quad \Delta TR_X=\sum_{k\in X}\left[P_1Q_1^k+P_2Q_2^k\right],$$

where the prices P_1 and P_2 satisfy (12) before elimination of X. Total costs, TC, will change by

$$(14)\quad \Delta TC_X\leqslant\sum_{k\in X}\left[(b+\beta)Q_1^k+bQ_2^k\right].$$

If the removal of the set X of consumers would result in a shift in the peak, then not all the capacity cost attributed to X can be saved, and (14) is a strict inequality. Otherwise, equation (14) is a strict equality.

With constant returns to scale, prices P_1 and P_2 which satisfy (12) are anonymously equitable (a) if, for any arbitrary X, the revenues of X are no greater than stand-alone costs of X

(15)

$$\sum_{k\in X}\left[P_1Q_1^k+P_2Q_2^k\right]\leqslant C\left[\sum_{k\in X}Q_1^k,\ \sum_{k\in X}Q_2^k\right],$$

and (b), if, for Y (the complement of X), the revenues of Y are no greater than stand-alone costs of Y

(16)

$$\sum_{l\in Y}\left[P_1Q_1^l+P_2Q_2^l\right]\leqslant C\left[\sum_{l\in Y}Q_1^l,\ \sum_{l\in Y}Q_2^l\right].$$

Both of these conditions are satisfied if and only if

$$(17)\quad P_1=b+\beta \text{ and } P_2=b$$

as we shall show.

These prices satisfy (15) and (16) whether or not there is a peak reversal. With no peak reversal (15) requires

$$(18)\quad \sum_{k\in X}\left[P_1Q_1^k+P_2Q_2^k\right] \leqslant\sum_{k\in X}\left[(b+\beta)Q_1^k+bQ_2^k\right]$$

and (16) requires

$$(19)\quad \sum_{l\in Y}\left[P_1Q_1^l+P_2Q_2^l\right] \leqslant\sum_{l\in Y}\left[(b+\beta)Q_1^l+bQ_2^l\right].$$

With a peak reversal, (15) requires

$$(20)\quad \sum_{k\in X}\left[P_1Q_1^k+P_2Q_2^k\right] \leqslant\sum_{k\in X}\left[(b+\beta)Q_1^k+bQ_2^k\right]$$

and (16) requires

$$(21)\quad \sum_{l\in Y}\left[P_1Q_1^l+P_2Q_2^l\right] \leqslant\sum_{l\in Y}\left[bQ_1^l+(b+\beta)Q_2^l\right].$$

Only the prices in (17) satisfy all of the conditions (18)–(21) and the budget constraint (12), and are therefore anonymously equitable. To demonstrate this, we need only show that $P_1=b+\beta$ and $P_2=b$ satisfy (20)

and (21) (relevant if a peak reversal occurs when the set X is removed) and that they are the only prices which satisfy (18) and (19) (relevant if no peak reversal occurs). First, prices in (17) satisfy (20) exactly, as is clear from inspection. Second, substituting $P_1=b+\beta$ and $P_2=b$ into (21) yields:

$$\sum_{l\in Y}\left[(b+\beta)Q_1^l+bQ_2^l\right] \leqslant \sum_{l\in Y}\left[bQ_1^l+(b+\beta)Q_2^l\right],$$

$$\sum_{l\in Y}\left[b\left[Q_1^l-Q_2^l\right]\right]\leqslant 0,$$

which is satisfied if $\Sigma_{l\in Y}Q_2^l\geqslant\Sigma_{l\in Y}Q_1^l$ (i.e., a peak reversal). Therefore $P_1=b+\beta$ and $P_2=b$ satisfy both (20) and (21) in the case of a peak reversal.

If there is no peak reversal, subtracting inequality (19) from (12) yields (noting Y is the complement of X)

$$\sum_{k\in X}\left[P_1Q_1^k+p_2Q_2^k\right] \geqslant \sum_{k\in K}\left[(b+\beta)Q_1^k+bQ_2^k\right].$$

Hence, (18) must hold at equality for all X, which is only possible if $P_1=(b+\beta)$ and $P_2=b$. This result is perfectly general since we have chosen any arbitrary X and its complement Y. In addition, it is also more restrictive than the subsidy-free result by commodity, as we shall show.

Applying the cross-subsidy test to our time of day example, neither time of day is providing a subsidy to the other so long as its revenues are no greater than its stand-alone costs of provision. With the profit constraint (12) binding, this is expressed as follows:

$$(22)\quad P_1Q_1\leqslant C(Q_1,0)=(\beta+b)Q_1;$$

$$(23)\quad P_2Q_2\leqslant C(0,Q_2)=(\beta+b)Q_2.$$

These yield $P_1\leqslant(\beta+b)$ and $P_2\leqslant(\beta+b)$.

According to the Incremental Cost version of the Cost Test, neither service is receiving a subsidy from the other so long as its revenues are no less than its incremental costs of provision. With (12) binding, this is expressed as follows:

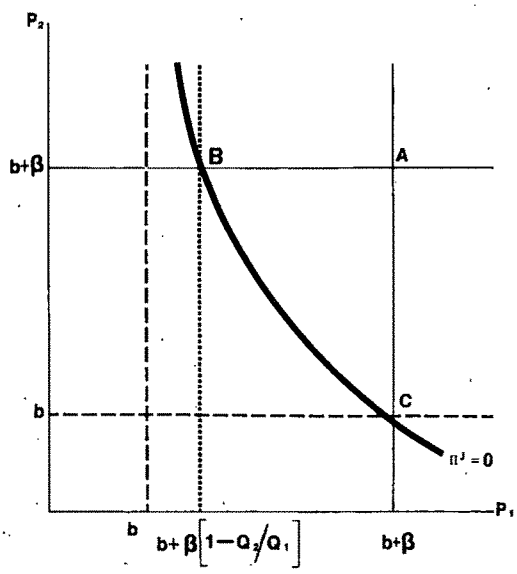

FIGURE 2

$$(24)\quad P_2Q_2\geqslant C(Q_1,Q_2)-C(Q_1,0),$$
$$\geqslant(\beta+b)Q_1+bQ_2-(\beta+b)Q_1,$$
$$\geqslant bQ_2;$$

$$(25)\quad P_1Q_1\geqslant C(Q_1,Q_2)-C(0,Q_2),$$
$$\geqslant(\beta+b)Q_1+bQ_2-(\beta+b)Q_2,$$
$$\geqslant\beta(Q_1-Q_2)+bQ_1.$$

These yield $P_2\geqslant b$ and $P_1\geqslant\beta[1-(Q_2/Q_1)]+b$. It can be readily seen that the prices in (17) which satisfy the condition for anonymous equity in (15) and (16) also satisfy the range of price combinations for subsidy-free pricing conditions by service (i.e., by period) in (22) through (25).

This result is illustrated in Figure 2 in which we graph P_1 with P_2. The stand-alone price levels are given by the constant $b+\beta$ and are marked by the solid lines intersecting at point A. The constant marginal operating costs b are given by the dashed lines. The dotted line marks the lower bound for

P_1 which satisfies the condition in (25). Price pairs which satisfy (24), (25), and the zero-profit constraint under joint production are indicated along the zero-profit line marked $\Pi^j=0$. Thus, in this simple example, prices are subsidy-free by commodity so long as prices are on the zero-profit line between points B and C inclusive. That is, prices which are less than stand-alone costs and greater than incremental costs can not involve cross-subsidy. Consumers are at least as well off under joint provision as under stand-alone provision.

By comparison, anonymously equitable pricing requires, from (17), that peak period 1 be priced at stand-alone cost while off-peak period 2 be priced at incremental cost. This occurs only at point C in Figure 2. Thus, anonymously equitable pricing is considerably more restrictive than subsidy-free pricing by commodity (or period).

III. Existence of Anonymously Equitable Prices

Is it always possible to find anonymously equitable prices, given subadditive costs? Faulhaber (1975) demonstrated the disquieting result that there are subadditive cost functions for which there are no subsidy-free prices. In view of Proposition 4, for these cost functions, there are clearly no anonymously equitable prices, either. Beyond the Proposition 4 result, can more be said concerning the existence of anonymously equitable prices?

Recently, the two concepts of sustainability and supportability have been introduced which relate quite closely to anonymous equity, and are useful in determining the achievability of anonymously equitable prices.

Definition: A natural monopoly with a demand function $Q(p)$ and cost function $C(Q)$ is *sustainable* if there exists a price vector p such that

(i) $p \cdot Q(p) = C(Q(p))$;

(ii) for any p', q with $p' \leq p$ and $q \leq Q(p')$, it is true that $p' \cdot q < C(q)$.

(Panzar and Willig, and Baumol, Bailey, and Willig.)

Definition: A cost function is *supportable* at $q>0$ if there exists a "price" vector p_q such that

(i) $p_q \cdot q = C(q)$;

(ii) $p_q \cdot y \leq C(y)$, for all y, $0 \leq y \leq q$.

(Sharkey and Telser; we use a local definition of supportability here, rather than the global definition of the original.)

Clearly if a price vector p is sustainable, then it must be anonymously equitable (simply examine $p'=p$ in condition (ii)). Further, if a price vector is anonymously equitable, then the cost function must be supportable at the market demand $q=Q(p)$, with $p_q=p$, the market prices. We have thus proved:

PROPOSITION 7: *Sustainability of the natural monopoly is a sufficient condition for anonymous equity to be achievable; supportability of the cost function at market demands is a necessary condition for anonymous equity to be achievable.*

This proposition enables us to draw upon the results in this literature for further conditions regarding the existence of anonymously equitable prices. Conditions sufficient for sustainability are obviously sufficient for the existence of anonymously equitable prices, and conditions necessary for supportability are necessary for our condition as well.

PROPOSITION 8: *If anonymous equity is achievable for every demand function (yielding nonzero demands), then the cost function exhibits declining ray average cost, that is, the cost function is subhomogeneous.* (Sharkey and Telser, 1978, Proposition 2.)

PROPOSITION 9: *If the cost function exhibits declining ray average cost and is "transray" convex (i.e., convex when restricted to a hyperplane $w \cdot Q = k$), then Ramsey prices (i.e., prices which maximize total surplus subject to a budget constraint) are anonymously equitable.* (Baumol, Bailey, and Willig, 1977; further technical conditions are listed in their Appendix.)

Our last sufficient condition follows from our Proposition 6.

PROPOSITON 10: *If* 1) *the cost function exhibits weak cost complementarities , and* 2) *demands are independent and "large" in the sense that the maximum revenue attainable for commodity i is finite and no less than the stand-alone cost for commodity i (at zero price), then anonymously equitable prices are achievable.*

PROOF:

Under *WCC*, Panzar and Willig show that there exists a core to the "cost game", for any quantity vector Q, that is, there exists a "revenue" vector $x=(x_1,\ldots,x_n)$ such that $\Sigma_{i\in N}x_i=C(Q)$ and $\Sigma_{i\in S}x_i\leqslant C(Q_S)$, for all $S\subseteq N$. What is not in general true is that any such core vector corresponds to the revenue vector generated by the market prices associated with Q. Hypothesis 2 is used below to show that there does exist a quantity vector whose corresponding market prices generate revenues in the core, and thus are subsidy-free. Applying our Proposition 6 yields the result that such prices are also anonymously equitable, under the hypothesis of *WCC*.

What remains to be shown is that there exists a quantity vector Q for which the market revenues $Q\cdot p(Q)$ lie in the core of the cost game associated with $C(Q)$. Let the revenues as a function of Q_i achieve a maximum $\bar{R}_i$ at $\bar{Q}_i$; further assume that a zero price elicits a finite demand Q_i^0, and that R_i is a continuous and strictly monotonic function of Q_i in the interval $\mathcal{Q}_i=[\bar{Q}_i, Q_1^0]$. Then the function R from $\mathcal{Q}=\mathcal{Q}_1\times\ldots\times\mathcal{Q}_n$ onto $\mathcal{R}=[0,\bar{R}_1]\times\cdots\times[0,\bar{R}_n]$ has a continuous inverse, where $\mathcal{Q}$ and $\mathcal{R}$ are Cartesian products. Now for each $Q\in\mathcal{Q}$, define $X(Q)=\{x\in R^n|\Sigma_{i\in N}x_i=C(Q)\}$ and $\Sigma_{i\in S}x_i\leqslant C(Q_S)$ for all $S\subseteq N$, i.e., $X(Q)$ is the core of the cost game with quantities Q (and is thus convex and compact). By *WCC*, $X(Q)\neq\phi$, for all $Q\in\mathcal{Q}$. For all $x\in X(Q)$, we have that $0\leqslant x_i\leqslant C(Q_i)\leqslant C(Q_i^0)\leqslant R_i$, so that $X(Q)\subseteq\mathcal{R}$. Therefore, we have a correspondence $X(R^{-1}(x))$ which continuously maps $\mathcal{R}$ into itself. Since $\mathcal{R}$ is compact and convex, as is $X(Q)$ for all $Q\in\mathcal{Q}$, the conditions of the Kakutani Fixed Point Theorem obtain (assuming C continuous), and there exists a fixed point of the correspondence, x^*, for which $x^*\in X(R^{-1}(x^*))$, that is, the revenue vector x^*, which corresponds to a market demand $Q^*=R^{-1}(x^*)$ and market prices $p(Q^*)$, is in the core of the cost game of Q^* and hence $p(Q^*)$ is subsidy-free. By Proposition 6, *WCC* implies that $p(Q^*)$ is also anonymously equitable.

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Metzler on Classical Interest Theory: Comment

By SYED AHMAD*

Lloyd Metzler's demonstration that the rate of interest is altered by the open market operations of the central bank, explicitly and crucially depends on the Pigou effect, and hence on the pre-existence of money in the economy.[1]

Once this is realized, John Wood's equation (10) (1980, p. 139), which reads:

$$(10) \qquad M=(1-\lambda)aP$$

would have to be written as

$$(10') \qquad M=(1-\lambda)aP+M_0$$

where M is the total quantity of money, M_0 the pre-existing quantity of money, λ the share of securities in the hands of the private sector (thus leaving $1-\lambda$ with the central bank), a the real value of the assets, and P the general price level. This would change Wood's (11) and (12), respectively, to the following:

$$(11') \qquad S\left(r, \frac{cy}{r}+\frac{M_0}{P}\right)=I(r)$$

$$(12') \qquad L(r)=\frac{1-\lambda}{\lambda}+\frac{M_0 r}{P\lambda cy}$$

where r is the rate of interest, and $cy/r=a$, the real value of the securities. Now r and P are the unknowns, which are simultaneously determined by (11′) and (12′). None of the problems raised by Wood on the basis of his (11) and (12) arise. Furthermore, by adding equation (10′) to Metzler's original four equations (which Wood has rewritten as (1)–(4)) and writing M/P for m, we can easily show that $dr/d\lambda>0$. This result represents Metzler's "nonclassical" theory of interest, which thus remains unaffected by Wood's requirement that securities be sold only at equilibrium prices.

The nonneutrality of money results essentially from the Pigou effect on the money existing at the time the open market operation takes place. The operation itself does not add or subtract real wealth in the private sector, as the real balances and real assets of equal value change hands through the operation. However, the change of the nominal money needed for this operation changes the general price level, and hence changes the real value of the money originally held by the private sector. This changed value of the original money, which forms a part of the total asset, changes the real value of the total asset when the value of the other part of the asset remains unchanged. This, in turn, changes saving through the Pigou efect, and consequently changes the rate of interest through the classical mechanism.

It may appear reasonable to ask: how did any money get into the system in the first place? The simple answer is that the question is irrelevant in the present context, since Metzler's concern is with an ongoing economy with money, and not with its genesis.

This is not meant to be a flippant answer, or an attempt to evade the issue. The *introduction* of money into a moneyless economy raises basically different issues from those raised by an *increase* in the quantity of money in an economy in which money already exists; and many, if not most, of the important propositions of monetary theory are meant to apply exclusively to an economy in which money is already in existence. The most famous of these is the quantity theory of money. If the initial quantity of money is zero, the quantity theory of money (or equiproportional increases in the quantity of money and the price level,) cannot even be defined, let alone established. But then, if the inability to deal with a zero quantity of initial money is no bar for the

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[1]Metzler's assumption of pre-existing money may also be inferred from his allowing the open market operation to *decrease*, as well as increase, the quantity of money in the economy (p. 97).

quantity theory of money to be considered a legitimate part of monetary theory, it should be no bar for Metzler's theory either.

The reason money cannot be introduced through Metzler's mechanism when we start with a moneyless economy is that, in his system (as in many others), it is not the nominal money but real balances which provide the relevant monetary variable, while the supply of money is defined only in nominal terms. Thus the supply of money cannot be *directly* incorporated into the system. Normally, it is the general price level which provides the link, and translates the supply of nominal money into real balances. In a moneyless economy, however, the "general price level" has no meaning. The link is absent, and thus there is no way for the nominal money to be introduced within the framework of the system.[2]

The *introduction* of money into a moneyless economy needs a different approach. The conventional explanation has been through treating this as technical change or innovation.[3] It is well known that an innovation, either in the product or in the process, by definition, alters the number or the nature of relationships (equations) of the system and hence alters the configuration of the equilibrium values of the variables.[4] Therefore, the introduction of money in a moneyless economy cannot, a priori, be assumed to be a neutral phenomenon. However, this is not a question that either Metzler or the quantity theorists have addressed. Their concern has been with an ongoing economy with money in it, and we have already seen that in this framework Metzler's theory of interest is not affected even if Wood's suggestion is incorporated into his system.

[2]Neither of Metzler's two types of operation can be directly used for introducing money in a moneyless economy. The operation of the first type is used by Meir Kohn in his comment on Wood, for introducing the initial M_1/P_1 through his equation (11). But even if we assign some meaning to M_1, where does the initial P_1 come from in such an economy? The untenability of this approach becomes even more obvious when John Wood, in his Reply, uses the same equation to derive $(dP/dM)(M/P)=1$. It can be directly seen (as I have noted in the text) that this equiproportional change in the quantity of money and the price level has no meaning with zero initial money. This last argument also applies to Metzler's operation of the second type.

[3]For example, by Harry Johnson. The traditional "historical" description of the introduction and evolution of money, from goat money to courie money, to metal and paper money, may be treated as distinct technical changes in the various stages of the evolution of money. Hence, as Johnson notes, not only the introduction of money, but also the changes in the medium which is used as money, may be considered technical change.

[4]In brief, for money to be introduced into a system which is already in equilibrium without it, something has to "give." Technical change neatly summarizes a multitude of those things.

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Metzler on Classical Interest Theory: Comment

By MEIR KOHN*

In a recent paper in this *Review*, John Wood has purported to find a new flaw in the theoretical framework of Metzler's "Wealth, Saving, and the Rate of Interest" beyond those already discussed by Jürg Niehans. It is the purpose of this comment to show that the only new flaws are in Wood's own reasoning.

Wood argues as follows. Metzler's system (p. 113) may be written

$$S(r,w)=I(r), \tag{1}$$

$$L(r)=m/\lambda a, \tag{2}$$

$$w=\lambda a+m, \tag{3}$$

$$a=cy/r, \tag{4}$$

where r is the rate of interest (yield on common stock), w is real private wealth, m is real private money holdings, a is the real value of common stock, λ is the proportion of common stock that is privately held, y is real national income, c is the proportion of income that goes to business profits, and S and I are real current savings and investment, respectively.

Wood reduces this to two equations in the two unknowns r and P:

$$S(r,\lambda cy/r+M/P)=I(r); \tag{5}$$

$$L(r)\cdot\lambda cy/r=M/P. \tag{6}$$

Considering a monetary change "of the first type"—an open market purchase of securities—Wood requires that the securities be purchased at the equilibrium price. That is, the central bank's balance sheet must read

$$(1-\lambda)cy/r=M/P. \tag{7}$$

Wood then combines (5), (6), and (7) to yield

$$S(r,cy/r)=I(r); \tag{8}$$

$$L(r)=(1-\lambda)/\lambda. \tag{9}$$

He concludes (a) "... that the equilibrium rate of interest is determined, as in the classical system, in the commodity market in contrast to Metzler's main thesis"; (b) "... that private wealth is independent of the central bank's security transactions" (p. 139); and (c) that "... the imposition of equilibrium trading on Metzler's system leaves the price level undetermined [it is absent from (8) and (9)] and causes the rate of interest to be overdetermined" (p. 140). In fact, none of these conclusions are correct.

To see this, consider a sequence of *two* open market operations. The first is the first ever made. The central bank creates a predetermined sum of dollars M_1 and uses it to purchase private securities at the equilibrium price P_1. That is,

$$(1-\lambda_1)P_1cy/r_1=M_1, \tag{10}$$

where P_1, r_1, and λ_1 also satisfy

$$S(r_1,\lambda_1cy/r_1+M_1/P_1)=I(r_1); \tag{11}$$

$$L(r_1)\lambda_1cy/r_1=M_1/P_1. \tag{12}$$

The result of imposing the constraint that securities be purchased at their equilibrium price merely converts a two-equation, two-variable system ((5) and (6)), r and P into a three-equation, three-variable system ((10), (11), and (12)), and r_1, P_1, and λ_1.

Now, substituting (10) into (11) we obtain

$$S(r_1,cy/r_1)=I(r_1), \tag{13}$$

so that Wood's conclusions (a) and (b) *are* valid for this initial open market purchase: neither the interest rate nor real private

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wealth are affected by the size of M_1. However, Wood's conclusion (c) does not hold. Given the rate of interest r_1 determined by (13), equations (10) and (12) determine λ_1 and P_1. Hence, the price level is not undetermined and the interest rate is not overdetermined.

Now consider a *second* open market operation. An additional sum of dollars M_2-M_1 is created and used to purchase additional private securities at the new equilibrium price P_2. That is,

$$(14) \qquad (\lambda_1-\lambda_2)P_2cy/r_2=M_2-M_1,$$

where P_2, r_2, and λ_2 satisfy

$$(15) \qquad S\left(r_2, \lambda_2\frac{cy}{r_2}+\frac{M_2}{P_2}\right)=I(r_2);$$

$$(16) \qquad L(r_2)\lambda_2\frac{cy}{r_2}=\frac{M_2}{P_2}.$$

Again we have three equations in three unknowns, but there are some differences. The balance sheet of the central bank has changed from

Assets: $(1-\lambda_1)cy/r_1$
Liabilities: M_1/P_1

to

Assets: $(1-\lambda_2)cy/r_2$
Liabilities: M_2/P_2
Net Worth: $(1-\lambda_1)(cy/r_2-cy/r_1)+(M_1/P_1-M_1/P_2)\equiv N.$

Real assets are no longer balanced by real liabilities. There is now a net worth item N, equal to the appreciation in the value of securities held prior to the new purchase plus the depreciation in real liabilities caused by the rise in prices.

Substituting (14) into (15) we obtain

$$(17) \qquad S\left(r_2, \frac{cy}{r_2}-N\right)=I(r_2).$$

Hence, neither of Wood's conclusions (a) nor (b) is valid here: N is a function of P_2 so that the rate of interest is no longer determined solely by the commodity market, but by the system as a whole; private wealth is no longer independent of open market operations as it depends on r_2 (itself dependent) and on N. Notice the "transfer" of wealth from individuals to the central bank, a phenomenon known as "forced saving" in the classical literature.

All subsequent open market operations would be similar in their effects to this second open market purchase.

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Metzler on Classical Interest Theory: Reply

By JOHN H. WOOD*

Lloyd Metzler's "Wealth, Saving, and the Rate of Interest" has played a useful role in the development of monetary theory. Perhaps most importantly, it has stimulated significant contributions to our understanding of the nature of the classical general equilibrium. Among these contributions are two that I had thought were widely accepted: (i) in order for money prices to be determined they must impinge on some quantity or quantities that are fixed in nominal (money) terms (i.e., money prices must "matter" in a "real sense); and (ii) there is no real balance effect and money is neutral in all-inside-money, equilibrium systems. Substantial portions of Don Patinkin's *Money, Interest, and Prices* are devoted to proofs and examples of these propositions.[1]

It is no criticism of Metzler to point out that his seminal work failed to contain all of the refinements and corrections that it inspired. Less understandable has been the failure of several writers to apply the contributions of Patinkin and others to Metzler's representation of the classical framework, with the consequence that we have been exposed to repeated demonstrations of nonclassical results from a so-called classical model. The purposes of my earlier paper were to bring Metzler's much used model into the mainstream of contemporary general equilibrium analysis and to derive the implications of that model when, as in other equilibrium systems, trading occurs only at equilibrium prices. I found that classical assumptions, when applied to Metzler's model, lead to standard classical results, such as the neutrality of money. This is true for both the inside- and outside-money versions of the model. In addition, because Metzler made inside money proportional to the price level, the application of classical equilibrium trading implies an indeterminate money supply and an indeterminate price level. All of this is familiar to Patinkin's readers.

In his opening discussion and equations (1)–(9), Meir Kohn fairly describes my restatement of Metzler's model with equilibrium trading. But he denies the two propositions stated above. His approach is to seek different results by means of an alteration in the assumptions. Instead of following Metzler[2] in letting M be endogenous while the central bank exogenously fixes λ, he reverses these assumptions by having the central bank fix M and letting λ be endogenous. The results of this switch, he claims, are that (i) the price level is determinate, and (ii) money is no longer neutral except in the case of the first open market operation.

Variations in assumptions often generate variations in results. However, the inability of the central bank to acquire real assets (whose nominal values are proportional to the price level) in exchange for money prevails no matter whether we let M or λ be the instrument of policy. Every increase in M causes an increase in P in the same proportion and leaves the central bank in possession of no more real assets than before the monetary injection. The indeterminacy of prices in a system in which fixed nominal claims are absent is, it appears, a robust result. These assertions may be demonstrated as follows.

Kohn's first open market operation is imposed on his equations (10)–(12) in the three unknown, r, P, and λ: "The central bank creates a predetermined sum of dollars M_1 and uses it to purchase private securities at the equilibrium price P_1" (p. 1094). He finds that r is not altered by the open market operation while λ falls from 1 to $\lambda_1 < 1$, where $(1-\lambda)$ is the proportion of securities (common stock, i.e., claims on real assets)

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[1]Especially see the page references given in fnn. 4 and 7 of my earlier article.

[2]See Metzler, pp. 107, 113–14, and my earlier paper, pp. 137–38.

owned by the central bank. But what is the evidence adduced in support of these "results"? The answer is "none" except a reproduction of my earlier demonstration that the public's wealth is independent of open market operations conducted at equilibrium prices, which in turn implies that the rate of interest is a real phenomenon. But what about λ_1 and P_1? Differentiating (10)–(12) with respect to M gives

$$dr/dM = d\lambda/dM = 0;\ (dP/dM)M/P = 1.$$

The price level has risen equiproportionally with M while the central bank, for the reason stated in the preceding paragraph, has acquired no securities.

These results might have been obtained by Kohn simply by inspection of (10)–(12). If equilibrium is stable and unique, an exogenous change in M is seen to cause a change in P in the same proportion with no alteration in r or λ. This is precisely the effect of a change in M when λ is fixed and the inside-money-supply equation (10) is suppressed. Whatever the intentions of Kohn and the central bank, the consequences are an injection of outside money in the amount M_1, a new money-supply equation,

$$(10') \qquad M/P = (1-\lambda)cy/r + M_1/P,$$

and a real balance effect because private wealth is now

$$(3') \qquad w = cy/r + M_1/P.$$

This gives us the standard inside-outside-money system in which, as stressed by Patinkin, and by John Gurley and Edward Shaw, injections of inside money, including Kohn's second open market operation, exert real effects.[3] These points also apply to Syed Ahmad's comment. He is, of course, also free to start his monetary economy off with a gift of helicopter money, although why the initial injection of money must *necessarily* take this form, without real costs or exchanges of wealth, is not clear.

In summary, it seems that Kohn and Ahmad agree with the main points of my paper, namely:

1) Open market operations in an all-inside-money general equilibrium system are neutral.

2) If all money is (and has been) gotten into the system through central bank purchases of commodities (or claims on commodities), the price level is indeterminate. It is difficult to see how such a monetary economy can even get started.

3) One way (but far from the only way) out of the dilemma, as implied by Kohn's analysis and pointed out explicitly by Ahmad and me, is an injection of outside money. (Further solutions are discussed toward the end of my earlier paper.)

[3]See fn. 7 in my earlier paper.

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Tariffs as a Means of Altering Trade Patterns

By WILLIAM J. RIEBER*

In the presence of a perfectly competitive market, a tariff cannot reverse trade flows. The imposition of a nonprohibitive tariff on an imported commodity merely reduces the volume of imports. The levy of a prohibitive duty eliminates trade; it does not cause the good to be exported. However, in the presence of a single domestic producer, the levy of a tariff on an imported commodity may lead the economy to begin exporting the commodity. In this paper I explore this latter case, examining also the welfare implications of such a tariff.

Consider an economy which, under free trade, imports a given commodity that is also supplied domestically by a single producer. All other markets are assumed to be perfectly competitive. The economy is assumed to be a price taker in the world market for this good; hence, the domestic producer is confronted with international competition in perfectly elastic supply. In Figure 1, P_w is taken to be the world price of the good;[1] D represents the (real income constant) domestic demand for the good; MR represents the marginal revenue derived from D; and MC depicts the producer's marginal cost. Under free trade, the domestic price equals the world price. The producer's output of $0Q_2$ units is sold domestically, and imports are Q_2Q_6 units.

If a tariff rate of t_1 is imposed on imports, the domestic price increases to $(1+t_1)P_w$. The producer's output increases to $0Q_3$ units and domestic consumption declines to $0Q_5$ units. The government is the recipient of tariff revenue equal to t_1P_w multiplied by Q_3Q_5. Although the profits of the producer's increase and additional revenue accrues to the government, together they are less than the loss in consumers' surplus. Accordingly, domestic welfare declines as a consequence

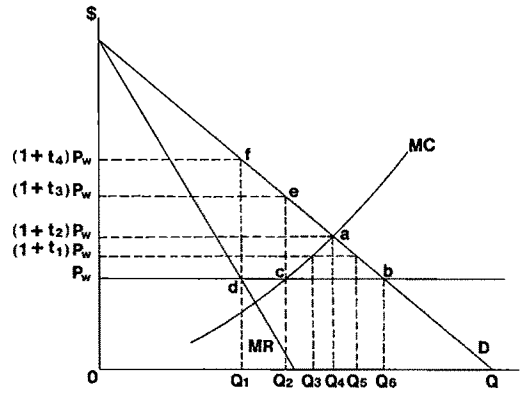

FIGURE 1

of the tariff. Indeed, as the tariff rate approaches that of t_2 in the figure, domestic welfare is correspondingly reduced. At the tariff rate of t_2, the economy ceases to engage in international trade in this commodity.

Tariff rates above t_2 will enable the producer to behave as a monopolist in the domestic market, that is, to price above marginal cost. For tariff rates between t_2 and t_3, the producer sets the domestic price equal to the world price plus tariff, with no foreign trade taking place. As the tariff rate is raised from t_2 to t_3, the gains in profit are more than offset by losses in consumers' surplus. Compared with tariff rate t_2, the additional deadweight loss associated with tariff rate t_3 is measured by the area *eac*. Compared with free trade, the total deadweight loss of tariff rate t_3 is measured by *ebc*. At this tariff rate the producer's output has returned to its free trade level. Consumption, though, is not at its free trade level; rather, it now equals domestic production.

Tariff rates above t_3 will prompt the producer to begin exporting. That is, at the tariff rate of t_3 the producer's marginal cost is equal to P_w, but is greater than the domes-

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[1]Zero transportation costs are assumed.

tic marginal revenue. Consequently, in response to tariff rates above t_3 the producer, while not altering production, raises his domestic price. As such, domestic consumption declines and domestic marginal revenue increases. Meanwhile, the producer exports the difference between his production and domestic consumption at the world price, thereby turning a commodity imported under free trade into an export. The producer is engaging in dumping here in that he is exporting at P_w and selling domestically at a price above P_w.

Once the tariff rate reaches t_4, the producer will not raise the domestic price in response to even higher tariff rates. At the domestic price of $(1+t_4)P_w$ the domestic marginal revenue, world price, and producer's marginal cost are all equal; therefore, it will not profit the producer to raise further the domestic price. The producer sells $0Q_1$ units in the domestic market and exports Q_1Q_2 units at price P_w.

Compared with the free trade equilibrium, tariff rates above t_3 neither alter domestic production nor generate any tariff revenue. Yet they do enable the producer to raise domestic price, severely restricting domestic consumption. This restriction of domestic consumption causes a marked divergence between domestic price and marginal cost, which prompts the producer to take advantage of the world market for the purpose of exporting. Note, however, that if the domestic marginal revenue curve had intersected the marginal cost curve before intersecting the world price line, then the producer would not exploit the world market, no matter how high the tariff rate.

Domestic welfare continuously declines as the tariff rate is raised from zero to t_4. Compared with free trade equilibrium, the tariff rate t_4 yields a deadweight loss to the economy measured by *bdf*. This area is equal to the loss of consumers' surplus, measured by $P_w bf(1+t_4)P_w$, minus the gain in profit, measured by $P_w df(1+t_4)P_w$. Compared with the prohibitive tariff rate t_2, the additional deadweight loss associated with tariff rate t_4 is measured by *afdc*. Intuitively, this pronounced reduction in welfare is a consequence of the economy now exporting a commodity in which it has a comparative disadvantage.

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Engineering and Econometric Interpretations of Energy-Capital Complementarity: Comment

By JAMES M. GRIFFIN*

In a recent paper in this *Review*, Ernst Berndt and David Wood provide a useful clarification of gross and net complementarity, pointing out that energy and capital can be *gross* substitutes in a production subfunction and yet *net* complements in the aggregate production function. Using this theoretical proposition, they attempt to reconcile the econometric findings of energy-capital complementarity with other studies finding energy-capital substitutability. Their reconciliation rests on the finding that those studies finding energy-capital substitutability considered only capital (K), labor (L), and energy (E). By omitting materials (M) one obtains only a gross elasticity. The net elasticity, which allows for the additional substitution between the *KLE* aggregate and M, can indicate energy-capital complementarity. In fact, *KLEM* studies generally find energy and capital complementarity.

The purpose of this comment is to question whether the "net" and the "gross" elasticity distinction provides such a reconciliation among the econometric results. I agree that this explanation tends to reduce the disparity between the original Berndt-Wood elasticity estimate and Griffin-Gregory. Yet, three independent sources of evidence suggest that the omission of M is not a sufficient explanation, and probably not even a major explanation for the disparity of findings.

First, the difference between the gross elasticity in a *KLE* submodel and the net elasticity in a *KLEM* model depends critically on the elasticity of substitution between M and *KLE*. Let us adopt the Berndt-Wood notation and consider their mathematical example which demonstrates the possibility of gross capital energy substitutability as in the Griffin-Gregory study with net capital-energy complementarity:

$$(1)\quad Y=F(K,L,E,M)=F^*[(K,L,E),M]$$
$$=F^{**}(V,M)$$

where

$$(2)\qquad V=v(K,L,E).$$

In equation (1), gross output (Y) is a function of capital (K), labor (L), energy (E), and materials (M) inputs. Assuming weak separability of capital, labor, and energy vis-à-vis materials, enables the simplification $F^{**}(V,M)$. In equation (2), the production subfunction describes the production technology within the V aggregate, consisting of capital, labor, and energy. Berndt and Wood are quite correct in noting that price and substitution elasticities based on the *KLE* model in equation (2), as in the Griffin-Gregory paper, for example, reflect only gross elasticities which will generally differ from the net elasticities obtained from estimating the four-factor *KLEM* model in equation (1).

Berndt and Wood proceed to show that the net price elasticity between energy and capital is always smaller than the gross price elasticity between E and K. Following equation (27) in Berndt and Wood, note that the net price elasticity between energy and capital (ε_{EK}) depends on the gross price elasticity (ε^*_{EK}), the cost share of capital in the V aggregate (S_{KV}), and the own-price elasticity of the V aggregate (ε_{VV}) in the $F^{**}(\ )$ aggregate function:

$$(3)\qquad \varepsilon_{EK}=\varepsilon^*_{EK}+S_{KV}\varepsilon_{VV}.$$

From equation (3), it is apparent that in terms of elasticities, the gross elasticity measured by Griffin-Gregory and other *KLE*

*University of Houston. I wish to thank Paul Gregory, Jeffrey Parker, and an anonymous referree for helpful comments. Tien Chongpeerapien performed careful research assistance.

studies,[1] will tend to overstate the substitutability between E and K. Furthermore, based on the Griffin-Gregory finding that $\varepsilon^*_{EK}=.15$ and the 1965 data showing $S_{KV}=.14$, a price elasticity for V slightly in excess of unity is sufficient to yield energy-capital complementarity in the net elasticity, that is,

$$\varepsilon_{EK}\leqslant 0 \text{ if } \varepsilon_{VV}\leqslant -1.07. \tag{4}$$

Thus one is lead to believe that the reconciliation of *KLE* studies showing *E-K* substitution with *KLEM* results showing *E-K* complementarity rests on the gross-net elasticity distinction, rather than the short-run/long-run hypothesis advanced in Griffin and Gregory.

The seemingly plausible result in equation (4) is not so plausible when one considers the conditions under which ε_{VV} is price elastic. By recasting equation (3) in terms of Allen partial elasticities of substitution, we can explore the implications of assuming ε_{VV} is price elastic. Both the gross and net Allen elasticity of substitution between E and K are related to their respective cross-price elasticities as follows:

$$\sigma_{EK}=\frac{\varepsilon_{EK}}{S_{KY}} \text{ and } \sigma^*_{EK}=\frac{\varepsilon^*_{EK}}{S_{KV}}. \tag{5}$$

Thus equation (3) can be rewritten as

$$\sigma_{EK}=\frac{S_{KV}}{S_{KY}}\sigma^*_{EK}+\frac{S_{KV}}{S_{KY}}\varepsilon_{VV}. \tag{6}$$

Since $F^{**}(\ )$ is linearly homogenous, $\varepsilon_{VV}=-\varepsilon_{VM}$. By the same argument as in equation (5), ε_{VM} can be rewritten as $S_{MY}\sigma_{VM}$. Consequently, equation (6) can be restated solely in terms of substitution elasticities and cost shares:

$$\sigma_{EK}=\frac{S_{KV}}{S_{KY}}\sigma^*_{EK}-\frac{S_{KV}}{S_{KY}}S_{MY}\sigma_{VM}. \tag{7}$$

Equation (7) is useful in several respects. First, it demonstrates that the bias in interpreting a gross-partial elasticity of substitution as a net-partial elasticity of substitution is not necessarily towards substitutability as in the case of simple cross-price elasticities. In fact, σ_{EK} can exceed σ^*_{EK} in a variety of circumstances. Second, this formulation enables one to consider the partial elasticity of substitution necessary to obtain net complementarity. For 1965, $S_{KV}=.144$, $S_{KY}=.055$, and the cost share of materials relative to total output, $S_{MY}=.619$. Taking the Griffin-Gregory estimates, $\sigma^*_{EK}=1.07$, we find

$$\sigma_{EK}\leqslant 0 \text{ if } \sigma_{VM}\geqslant 1.73. \tag{8}$$

Thus the Berndt-Wood reconciliation rests on an elasticity of substitution between materials and K, L, E of 1.7 just to obtain a zero net elasticity of substitution. To reconcile Berndt and Wood's original point, estimate $\sigma_{EK}=-3.22$ with Griffin and Gregory's $\sigma^*_{EK}=1.07$, the elasticity of substitution between materials (M) and nonmaterials (V) would have to be 3.7.

Is there any evidence to suggest that the elasticity of substitution between materials (M) and nonmaterials (V) is greater than 1.7 (or equivalently that ε_{VV} is price elastic)? Traditionally, substitution between materials and nonmaterials has been implicitly disregarded with most studies examining capital-labor substitution in a value-added framework. Similarly, Wassily Leontief's work on input-output analysis suggests rather low values for σ_{VM}. Even the Berndt-Wood data indicate σ_{VM} is well below unity indicating that the net elasticity of substitution between K and E exceeds the gross substitution elasticity reported in Griffin and Gregory. Using the Berndt-Wood data for capital, labor, and energy prices and cost shares, a divisia price index for V was calculated and the function $F^*(V, M)$ was estimated as in (1). Note that actual prices were used rather than instruments as in the original Berndt-Wood model. For 1971, the implied value for σ_{VM} was .60 with a standard error of .06. While their tests for the existence of such a *KLE* aggregate failed for their data set, it is nevertheless

[1]For other *KLE* studies showing *E-K* substitution, see Robert Pindyck, and Robert Halvorsen and John Ford.

amusing that their data fail to support the magnitude of substitution elasticity required to support such a reconciliation.

The second piece of disquieting evidence leading one to question the Berndt-Wood reconciliation is the following proposition: barring problems of specification error, due to failure of M separability with KLE, wouldn't one expect to find σ^*_{EK} to be substitutes in their data sample? If the explanation is simply that KLE studies left out M, then shouldn't dropping out M from their $KLEM$ model yield results more or less consistent with gross substitutability between energy and capital? Using the Berndt-Wood data, a KLE model was estimated treating prices as exogenous. The results for 1971 indicate gross energy-capital complementarity ($\sigma^*_{EK} = -1.31$, with a standard error of .19). While this result does tend to reduce the disparity between the two sets of results, it is hardly consistent with other KLE studies, suggesting that other factors account for these differences.

Finally, to the extent that recent additional studies including all four factors ($KLEM$) find EK substitutability, the gross-net elasticity distinction cannot offer a complete explanation. In earlier studies of four key energy-consuming industries using a pseudo data approach, I found that energy-capital substitutability in two of the four industries (electricity generation and petrochemicals). Petroleum refining exhibited energy-capital complementarity while the iron and steel industry revealed approximately a zero partial elasticity of substitution. These results are interesting because they avoid the short-run/long-run controversy that exists between time-series and cross-sectional or pooled data sets. In the generation of the pseudo data, the industry process models were solved for the long-run cost minimizing inputs corresponding to various input price vectors. It is interesting to note that since capital included pollution abatement capital, these results probably understate the substitution response between energy and conventional capital because energy and pollution capital tend to be complementary.

Another interesting observation pertains to Berndt and Wood's suggestion that K and E form an aggregate. Such a simplification is not supported by the above industry level studies as it was found that energy itself does not form an aggregate. Obviously, the assumption of an energy aggregate enables considerable theoretical and empirical simplifications which probably more than offset the sacrifice in reality for addressing a variety of questions. The adoption of a K-E aggregate for theoretical and empirical analysis is even more restrictive and seems unlikely to compensate in simplicity for the loss in reality.

In sum, substantial differences persist among econometric studies of energy-capital substitution even after allowing for differences between net and gross elasticities. I am sure that Berndt, Wood, and other participants would join me in emphasizing the large confidence intervals that must be attached to any estimate. The current multiple directions of research emphasizing alternative specifications (alternative flexible functional forms, homothetic vs. nonhomothetic technologies, alternative types of technical change, etc.), capital measurement methods, dynamic specifications, and data bases (time-series, intracountry pooled, intercountry pooled samples and pseudo data) are to be viewed as a healthy response to an unanswered question.

I. A Postscript on Measurement Issues[2]

In their reply to this comment, Berndt and Wood have shifted the focus from "gross" vs. "net" elasticity measures to the issue of measurement error in the original Griffin-Gregory intercountry data. In our paper, we shared this concern, noting that it is difficult to insure comparability among countries that have different tax systems, different methods of gathering and reporting data, and different accounting procedures.

We are indebted to Berndt and Wood for their finding that the OECD and the U.S. capital share data are not conceptually the same, contrary to our original presumption

[2]Paul Gregory joins me as a coauthor in this last section.

This matter has been dealt with in the literature subsequent to the appearance of our 1976 paper, not without further pitfalls being encountered by other researchers.[3]

But where does the latest Berndt-Wood correction leave us in the fundamental issue of long-run capital-energy substitution? We must emphasize that their results remove two troublesome features of our original model, namely, the low level of statistical significance of σ_{KE} and the low value of σ_{KL} for the United States. With Berndt and Wood's revised data (that purport to correct for our omission of working capital from the U.S. data), our original model appears to be cleansed of these problems. Thus, Berndt and Wood appear to have succeeded in substantially strengthening our original findings of *K-E* substitution.

Berndt and Wood illustrate graphically their own point about the difficulties of deriving conceptually comparable data. Our own data were carefully devised from individual country yearbooks to eliminate indirect business taxes from the residual capital share. Throughout, we made sure that output was measured in factor costs. For some reason, Berndt and Wood have concluded that we have included indirect business taxes (*IBT*) in our capital shares, and they have even reconstructed their data to include *IBT*. Insofar as their recalculated U.S. data show an increase in the capital share from .143 to .291, and the cost of working capital constitutes only a fraction of physical capital costs, it is apparent that their results must depend heavily upon their erroneous inclusion of *IBT* in their adjusted data. These results have little meaning as no one contends that *IBT* should be included in the capital share. It would be useful for Berndt and Wood to report revised results that omit *IBT*.

As Berndt and Wood suggest, it would be desirable to correct for the missing factors in our original model—for material shares, for corporate tax differences, and so on. Yet they must recognize that a study of international differences in corporate taxation and its incidence would be a multiyear and multinational project that only an international organization could undertake. Calculation of material shares in an intercountry cross section is also not feasible because of differences in vertical and horizontal integration among countries. These were problems of which we were aware, and they were duly noted as caveats.

Finally, we must ask what the basic outcome of this exchange is. Initially, Berndt and Wood contended that the Griffin-Gregory *K-E* substitution result was the consequence of the omission of *M*. As demonstrated above, Berndt and Wood's own data fail to support this conclusion. In their reply, Berndt and Wood (after strengthening the results of our original model) now contend that conceptual differences in the measurement of capital are the cause of the discrepancies in our two results. For this to be demonstrated, we suggest that Berndt and Wood recalculate their data so that they are indeed conceptually comparable to our own. In sum, Berndt and Wood have sequentially advanced two alternative explanations for our finding of *K-E* substitution. As shown above, the first is empirically invalid and the second rests on a conceptual data error. We continue to believe that a pooled intercountry sample is likely to offer more reliable estimates of long-run *K-E* substitution relationships than the U.S. aggregate, time-series approach advanced by Berndt and Wood.

[3]For example, see B. C. Field and C. Grebenstein.

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Engineering and Econometric Interpretations of Energy-Capital Complementarity: Reply and Further Results

By ERNST R. BERNDT AND DAVID O. WOOD*

We are grateful for this opportunity to respond to comments of James Griffin on our earlier paper. In this reply, we will (i) deal explicitly with issues raised by Griffin; (ii) assess Griffin's contributions to the process of reconciling empirical evidence; and (iii) put forward new evidence on what accounts for differences in point estimates of capital-energy (K-E) elasticities.

Before proceeding, we think it important to note that our original proposition remains unchallenged: econometric findings of K-E complementarity and engineering notions and estimates of K-E substitutability can be entirely consistent with one another. The vehicle we used to demonstrate this basic harmony was a careful definition of the elasticity concept: in particular, we distinguished net from gross elasticities. We then used this same analytical framework to clarify differences between Griffin and Gregory (G-G) and our (B-W) econometric estimates of K-E substitutability.[1] Use of the gross-net distinction enabled us to reduce differences in the G-G and B-W point estimates of K-E price elasticities, and in fact although point estimates still differed, confidence intervals were sufficiently large so that G-G estimates were not statistically different from K-E complementarity.[2] What we did not do in our 1979 paper, nor did we intend to do, was to provide a complete reconciliation of all G-G and B-W point estimates of elasticities.

To see how different and pervasive the B-W and G-G elasticity estimates are—in particular, that differences are not restricted to K and E—in Table 1 we present the own- and cross-price elasticity estimates from the original G-G study (row 1), and estimates based on B-W data, but excluding M (row 2). Comparing these estimates, we see that substantial differences occur between inputs other than K and E, namely, between elasticities for K and L, L and E, and for all the own-price elasticities. For example, the G-G estimate of the gross price elasticity ε^*_{LK} for the United States in 1965 in 0.01.[3] This estimate is suspiciously low, it is practically the fixed-coefficient case. The corresponding net price elasticity ε_{LK} must by equation (26) in our 1979 paper be even smaller. In general, when M is excluded from the B-W data, substantial differences still remain so that other factors must contribute to differences in estimates.

I. Issues Raised by Griffin

Griffin questions the extent to which net and gross elasticity differences reconcile the disparity between the B-W and G-G estimates, both analytically and empirically. Analytically, Griffin shifts from the price elasticities used by B-W to Allen elasticities, and notes that when Allen elasticities are employed, net elasticities are not necessarily smaller than gross elasticities. This raises the issue of which elasticity measure—price (ε_{ij}) or Allen (σ_{ij}) —is preferable.

Two reasons underly our preference for price elasticities. First, since $\sigma_{ij} = \varepsilon_{ij}/S_j$ (where the cost share of the jth input is Sj), differences in cost shares, especially small

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[1]See Griffin and Paul Gregory, and our earlier article.

[2]Here we follow G-G in their use of t-statistics and confidence intervals of elasticity estimates, even though the statistical foundations underlying this have not yet been established.

[3]Taken from Griffin and Gregory's Table 3, p. 852.

TABLE 1—COMPARISON OF VARIOUS ELASTICITY ESTIMATES, ORIGINAL AND REVISED G-G AND B-W DATA FOR U.S. MANUFACTURING 1965

	ε^*_{KK}	ε^*_{KL}	ε^*_{KE}	ε^*_{LK}	ε^*_{LL}	ε^*_{LE}	ε^*_{EK}	ε^*_{EL}	ε^*_{EE}
1. G-G	−.18	.05	.13	.01	−.12	.11	.15	.64	−.79
	(.28)	(.08)	(.11)	(.05)	(.05)	(.02)	(.14)	(.10)	(.11)
2. B-W	−.41	.52	−.11	.10	−.17	.07	−.15	.45	−.30
	(.05)	(.05)	(.03)	(.01)	(.01)	(.01)	(.04)	(.03)	(.03)
3. G-G Rev.	−.65	.51	.14	.29	−.35	.06	.44	.36	−.80
	(.06)	(.04)	(.04)	(.04)	(.05)	(.03)	(.03)	(.10)	(.12)
4. B-W Rev.	−.61	.56	.05	.27	−.31	.04	.16	.25	−.41
	(.06)	(.04)	(.02)	(.02)	(.02)	(.01)	(.06)	(.05)	(.04)

Source: Wood and Hirsch. Row 1 taken from Griffin and Gregory (1976a, Table 3): row 2 based on B-W data excluding M; row 3 based on revised U.S. data for G-G study; and row 4 based on revised data for B-W study. Rows 2, 3, and 4 are based on Zellner estimation, and maximum likelihood estimates of elasticities. Standard errors in parentheses are based on the approximation method of Lawrence Klein.

cost shares like energy, induce more volatile variations in Allen elasticities, and thus needlessly obfuscate comparison of elasticity estimates among studies and countries. Use of the relatively scale-free price elasticities mitigates this comparability issue considerably. Secondly, as shown in our earlier paper, the net and gross price elasticities are related by the simple additive relationship,

$$(1) \qquad \varepsilon_{EK}=\varepsilon^*_{EK}+S_{KV}\varepsilon_{VV}.$$

By contrast, the relationship between the Allen net and gross elasticities introduces unnecessary scaling complications. Note that Griffin's equation (7) can be written as

$$(2) \qquad \sigma_{KE}=\frac{1}{S_{VY}}(\sigma^*_{KE}-\sigma_{VM})+\sigma_{VM},$$

which is more cumbersome than (1). Parsimony and a preference for a relatively scale-free elasticity measure counsels use of price rather than Allen elasticities. Griffin's analytical comment on net and gross Allen elasticities needlessly entangles interpretation, and makes no contribution to the difficult task of comparing elasticity estimates.

Empirically, Griffin focuses attention on the algebraic relation between gross and net elasticities, first to obtain sign reversals for σ_{KE} and σ^*_{KE}, ε_{EK} and ε^*_{EK}, then to equate G-G and B-W estimates of ε_{EK} and σ_{KE}, and finally to evaluate ε_{EK}, σ_{KE} using G-G data and a specific estimate of σ_{VM}. By an algebraic twist, the value of ε_{VV} necessary to induce a sign reversal between ε_{EK} and ε^*_{EK} is $-\sigma^*_{KE}$.

$$(3) \qquad \varepsilon_{EK}=\varepsilon^*_{EK}+S_{KV}\varepsilon_{VV}=S_{KV}(\sigma^*_{KE}+\varepsilon_{VV}).$$

Hence if $\varepsilon^*_{EK}>0$, $\varepsilon_{EK}\gtreqless 0$, as $|\varepsilon_{VV}|\lesseqgtr\sigma^*_{KE}$. Although Griffin focuses attention on values of ε_{VV} necessary to induce sign reversals in the K-E elasticities, the same procedure can be undertaken for other inputs simply by "reading off" from (3) the appropriate Allen elasticity. For sign reversal of K-L or L-E price elasticities, $\varepsilon_{VV}\leqslant -.06$ and $-.87$, respectively, is necessary. The case of K and L is of particular interest. Using Griffin's result that $\varepsilon_{VV}=-.375$, K-L gross substitutability and net complementarity is implied.[4] Truly there is much to puzzle about between the two sets of results, much more than just the K-E net-gross sign reversal.

Griffin's third and final piece of evidence in support of the notion that exclusion of M is not important concerns results from pseudo data, a technique which he has pioneered. The four studies cited by him include the full gamut of results of E-K substitutability,

[4]In the original G-G study with country intercepts (their Model II), point estimates of σ^*_{KL} were actually negative (−.2), implying gross K-L complementarity and even greater net K-L complementarity.

complementarity, and essentially independence, and thus appear to have no bearing on whether M was omitted. Space considerations preclude a full review of these studies. We note in passing, however,that the reliability of pseudo data techniques has been questioned in papers by G. S. Maddala and R. Roberts.[5] Moreover, comparable outputs are not held constant in the four Griffin pseudo data studies, thus again complicating comparison of elasticity estimates.

II. Assessment

Having responded to the analytical and empirical questions raised by Griffin in his comment, we now consider the issue that underlies the entire discussion, namely, why have econometric estimates of K-E substitutability differed.

A central theme in the original Griffin and Gregory paper was that differences in K-E elasticity estimates can be attributed to choice of data base and dynamic versus static considerations. In particular, according to G-G, cross-section data are more likely to yield estimates of long-run substitution responses, while time-series data tend to generate estimates of short-run responses. Griffin and Gregory used pooled cross-section, time-series data and argued that "... our data provide a particularly robust sample as the range of input price variation is far greater than in the previously cited studies ... [moreover]... observations between countries will tend to reflect long-run adjustments, as price differences tend to be the result of long-standing national tariff, indirect tax, and subsidy policies" (p. 847). Although G-G cite other authors who have made similar a priori claims, the G-G data and results offer very little support for this hypothesis. In particular, G-G are unable to reject the null hypothesis that slope coefficient estimates based on only time-series data for each country are equal across countries. Adding cross-sectional variation in data does not improve the statistical fit significantly.[6] Hence the credibility of the G-G claim that their pooled cross-section, time-series data base considerably improves and sharpens long-run elasticity estimates is called into question by their own data and results.

More generally, the issue of cross-section, time-series, and long-run, short-run elasticity estimates has been considered in a recent paper by David Stapleton, who demonstrates rigorously that the problem is not just one of data variation, but also of model specification. Until recently, dynamic models of industrial demand for energy have been based essentially on static optimization plus an *ad hoc* specification of the adjustment process.[7] However, energy demand models based on explicit dynamic optimization and endogenous adjustment paths are now available, and have been implemented empirically. For example, using U.S. time-series manufacturing data, C. J. Morrison and Berndt find that E-K complementarity is greater in the long run than in the short run, contrary to the a priori assertions of G-G. Similar findings based on more disaggregated U.S. two-digit manufacturing time-series data have been reported by M. G. S. Denny, M. A. Fuss, and L. Waverman, with fourteen of eighteen industries showing $\varepsilon_{KE}, \varepsilon_{EK}<0$. Using U.S. manufacturing data, 1958-77, J. R. Norsworthy and M. J. Harper find that estimates of E-K complementarity are greater when dynamic rather than static specifications are employed.

We conclude, therefore, the G-G hypothesis that differences between G-G and B-W are due principally to time-series (short-run) versus cross-section (long-run) data bases is not likely to be true; (i) it is not true with their data; (ii) in general it should not be expected to be true since the specification of the underlying dynamic model is also of critical importance; and (iii) recent evidence based on an explicit dynamic optimization framework finds evidence of increasing rather than decreasing K-E complementarity as adjustment to long run equilibrium takes place.

But if differences in K-E elasticity estimates cannot be explained sufficiently well by distinctions between gross and net price

[5]Also see Griffin (1981b, c).

[6]See G-G, pp. 851–52, and Table 1A, p. 856.

[7]For a survey of various dynamic models, see Berndt, C. J. Morrison, and G. C. Watkins.

elasticities, by time-series versus cross-sectional data bases, or by static versus dynamic optimization, to what can these differences be attributed? One other possibility, that differences are due to data measurement issues, is considered briefly by Griffin, who concludes that "... the measurement error problem seems likely to be of minor consequence... although it cannot be ruled out as potentially important" (1981a, p. 74). Recent research results by Wood and R. B. Hirsch, however, suggest that possibilities for reconciling the G-G and B-W substitution elasticity estimates on the basis of data measurement issues are very promising.

III. New Evidence

Wood and Hirsch have recently shown that much of the variation in G-G and B-W elasticity estimates results from three components including differences in (i) the G-G approach to measuring capital and labor expenditures in the United States versus other countries; (ii) treatment of taxes in the measurement of capital service price (P_K); and (iii) treatment of nonphysical capital in measuring capital service expenditures ($P_K K$). Here we summarize the results from that study.

First, the G-G data for U.S. shares of K and L are quite different from the values for other countries in their sample. The ranges of G-G shares for K, L and E are presented in Table 2 for the United States (col. 1) and for all other countries (col. 3). The significant differences could not be explained by reference to the G-G data appendix and, more importantly, could not be replicated by appeal to the source data documented in that appendix. Accordingly a revised set of U.S. expenditure shares consistent with the data appendix instructions and source data were constructed. Ranges for the revised shares are presented in Table 2, column 2, and are seen to be consistent with the ranges for other countries in the sample.

Use of the revised accounts changes the original G-G elasticity results substantially, and reduces some of the differences with the B-W results. Results are presented in Table1, row 3. Most significantly, ε^*_{KK} and ε^*_{LL} are much higher (more negative), ε^*_{KL}, ε^*_{LK}, and ε^*_{EK} are also larger, while ε^*_{LE} and ε^*_{EL} are smaller.

TABLE 2—RANGE OF VALUES FOR G-G EXPENDITURE SHARES ORIGINAL AND REVISED FOR THE UNITED STATES; ORIGINAL FOR OTHER COUNTRIES

Shares	U.S. Original	U.S. Revised	Other Countries
K	.139–.149	.271–.308	.261–.447
L	.707–.746	.578–.631	.440–.646
E	.116–.148	.098–.121	.053–.184

Second, while B-W measure P_K accounting for tax variables, G-G do not incorporate taxes in their measure because of data availability problems. Instead, G-G compute $P_K = (r+\delta)q_A$ where r=nominal rate of return, δ=rate of depreciation, and q_A=asset price index of new durable capital. Using the G-G concept, Wood and Hirsch recalculate P_K for U.S. manufacturing employing the B-W data for r, δ, and q_A, 1947–71. The simple correlation coefficient between this new measure of P_K and the original B-W measure is .71.

Third, G-G's measure of $P_K K$ is computed as value added minus the wage bill ($P_L L$), while B-W calculate an independent measure of K, and then compute capital expenditures as the product of the independent estimates of P_K and K. Thus the G-G measure of $P_K K$ includes working capital, returns to land, and indirect business taxes, as well as returns to physical capital, while P_K is a measure only of the physical capital service price component.[8] To evaluate the effect of this inconsistent treatment of P_K and $P_K K$, Wood and Hirsch calculate $P_K K$ using the G-G procedure, together with manufacturing value added and the B-W wage bill, and then calculate revised B-W factor shares.[9]

As shown in row 4, Table 1, when B-W data are revised to reflect G-G definitions of

[8]B. C. Field and C. Grebenstein evaluate elasticities based on data for physical capital, working capital, labor, and energy for ten U.S. manufacturing industries, 1971. They report K-E complementarity for the physical measure of capital, and K-E substitutability for working capital and energy. For comments, see Griffin (1981a).

[9]Mean values of original and revised B-W shares are, respectively, .143 and .291 for S_K, .736 and .609 for S_L, and .121 and .100 for S_E.

variables, significant substitutability is found between all inputs, including *K-E*. As shown in row 3, when the G-G data for U.S. *K* and *L* expenditures are constructed using procedures conforming with those for other countries, the revised G-G and B-W results are comparable, except for ε^*_{EK}, ε^*_{KE}, and ε^*_{EE}. Why these differences persist is puzzling. Note, however that for the revised G-G data, ε^*_{LK} is increased from 0.01 to 0.29, a more plausible result. Also, each elasticity estimate is now statistically different from zero. In the original G-G results only three of nine were significant, notably excluding ε^*_{LK}, ε^*_{EK}, and ε^*_{KE}.

In concluding their 1976 paper, Griffin and Gregory "... readily admit to potential measurement error..." (p. 855) in their approach. The Wood and Hirsch study documents the critical role of data issues in the G-G study, making clear just how important the sequence of measurement errors was in determining their *K-E* substitutability results. An implication of the Wood and Hirsch study is that if international factor accounts are to be used in future demand studies, it is essential that data be constructed with common definitions across countries, that tax variables be included, and that capital price and quantity be treated consistently.

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Basic Research and Productivity Increase in Manufacturing: Additional Evidence

By ALBERT N. LINK*

In a recent paper in this *Review*, Edwin Mansfield illustrated empirically (using a sample of ten petroleum and six chemical firms) that firm rates of productivity change are related to the amount of company-financed basic research performed, *certeris paribus*. In this note additional evidence is presented which is supportive of Mansfield's findings. This analysis is based on a sample of fifty-one major manufacturing firms active in *R&D*: it is unique in that the impacts of company-financed and government-financed basic research expenditures are considered determinants of productivity growth.

The following model was estimated:

$$(1) \quad \rho_i = \beta_0 + \beta_1 CB_i + \beta_2 CD_i + \beta_3 GB_i + \beta_4 GD_i + \beta_5 U_i + \varepsilon$$

where ρ_i is the average annual rate of change in total factor productivity between 1973 and 1978 in the ith firm; CB_i and CD_i are the ratio of company-financed basic research expenditures to net sales in the ith firm and the ratio of company-financed applied research plus development expenditures to net sales in the ith firm; GB_i and GD_i are the ratio of government-financed basic research expenditures to net sales in the ith firm and the ratio of government-financed applied research plus development expenditures to net sales in the ith firm; U_i is the percent of unionization in the 3-digit industry in which the firm performs its main operations; and ε is an error term.[1]

The least squares results are[2]

$$(2) \quad \rho_i = \underset{(-2.07)}{-1.37} + \underset{(3.87)}{2.31} CB_i + \underset{(1.83)}{0.19} CD_i + \underset{(2.13)}{1.17} GB_i - \underset{(-0.31)}{0.002} GD_i - \underset{(-1.83)}{0.025} U_i; \qquad R^2 = 0.43.$$

t-statistics are reported in parentheses.

These findings confirm Mansfield's proposition that company-financed basic research is a significant determinant of firm productivity growth. In addition, these results suggest that government-financed basic research is also a significant determinant. Previous researchers (for example, see Nestor Terleckyj) using a similar model and industry data found that government-financed *R&D* (as a total) has no statistical impact on industry productivity growth and concluded

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[1]The fifty-one firms represent seven manufacturing industries: aircraft and missiles (3 firms), chemicals (12 firms), electrical equipment (4 firms), machinery (12 firms), petroleum (10 firms), scientific instruments (2 firms), and transportation equipment (8 firms). The rate of change in total factor productivity was estimated with data from Compustat (see my 1981 book). Data pertaining to the percent of each firm's total *R&D* expenditures that are company- and government-financed, disaggregated into basic, applied, and development, were obtained by survey and correspond to 1976. These percentages were imputed to the firm *R&D* estimates reported by Compustat for 1976. Unionization data relate to the percentage of workers in each 3-digit industry who are covered by collective bargaining (see Richard Freeman and James Medoff).

[2]An applied research to sales ratio and a development to sales ratio for company- and government-financed expenditures were entered separately in a similar regression. The estimated coefficients on the applied research term and the development term were not significantly different from each other, regardless of source of financing. Those results are not reported. An alternative model was also estimated, where ρ_i was regressed on $(CB_i + CD_i)$, $(GB_i + GD_i)$, and U_i. The results imply that, between 1973 and 1978, the marginal rate of return from total company-financed *R&D* was about 38 percent and from total government-financed *R&D*, about 11 percent.

that government contracted *R&D* is not part of the relevant *R&D* investment of an industry. The results reported here suggest that the basic portion of government-sponsored *R&D* is an important part of the *R&D* investments of a firm.

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Report of the Committee on Political Discrimination

The Executive Committee of the American Economic Association has authorized publication of the following account relative to a charge brought to its Committee on Political Discrimination by Peter G. Bohmer, formerly of the Department of Economics, San Diego State College (now San Diego State University).

Circumstances of the Case

San Diego State University is part of the nineteen-campus California State University system. The Chancellor of the system throughout the period considered has been Glenn S. Dumke. The charge of political discrimination was brought by Bohmer against the action of Chancellor Dumke in overruling, on May 5, 1972, the recommendation of faculty and administration of San Diego State College that he be reappointed to probationary status in his rank as Assistant Professor.

On campus, Bohmer's assignment included the teaching of radical political economy. He also served as advisor to student groups concerned with antiwar and antiracism issues. Off campus, in the role of private citizen, Bohmer was active in radical politics. His off-campus activity gave rise to harrassment of Bohmer, both off campus and on campus. The harrassment was carried out with funds provided by the Federal Bureau of Investigation, as documented by the American Civil Liberties Union and by the U.S. Senate Select Committee on Domestic Intelligence. On campus, students having different political views brought charges of unprofessional conduct against Bohmer, and students supportive of Bohmer and of views expressed by him engaged in a series of demonstrations.

Chancellor Dumke, acting under authority of the State Administrative Code, temporarily assumed the role of President of San Diego State College and overruled faculty and administration recommendations favorable to Bohmer's reappointment, citing Bohmer's conduct, particularly his role in student demonstrations. That action was preceded by a disciplinary proceeding in which he was exonerated of all charges, and by the following: a report by a consultancy committee of faculty from outside institutions nominated by the American Association of University Professors at the invitation of the acting president, a faculty grievance committee hearing, and an action by the Faculty Senate, the outcome of each proceeding being favorable to Bohmer.

In the period through mid-1978, faculty union and civil rights organizations unsuccessfully supported Bohmer through court procedures at state and federal levels.

AEA Inquiry Panel

In response to a request by Bohmer to the Committee on Political Discrimination, an Inquiry Panel was appointed on July 21, 1978 by the Chair of that Committee, Carl M. Stevens. Those named to the Panel were John G. Gurley (Stanford University) and Richard J. Zeckhauser (Harvard University), with William B. Simpson (California State University, Los Angeles) as Chair. The Inquiry Panel completed its report (110 pp.) on August 29, 1980.

While the charge pertains to an action by the Chancellor of the California State University System, the Panel's report also conveyed the Panel's perception of the situation at department and at campus administration levels. The receptivity of the Department of Economics at San Diego State to individuals of diverse political beliefs was recognized. Through appropriate appointments and curricular offerings, the department provided students with access to a variety of viewpoints, including Marxian economics. The Panel did not find political discrimination originating with the campus level administration.

The principal finding by the Inquiry Panel is quoted below:

> With respect to the action by Chancellor Glenn S. Dumke in overruling, on May 5, 1972, the recommendation of faculty and administration of San Diego State College that the political activist Professor Peter G. Bohmer be reappointed to probationary status in his rank as assistant professor in the Department of Economics of that institution, it is the considered judgment of the Inquiry Panel that there was political discrimination in the nonreappointment of Professor Bohmer, taking into account that the reasons given by Chancellor Dumke were not established as compelling, that the Chancellor's differences with Professor Bohmer on matters of belief which are essentially political in nature were an explicit basis for the Chancellor's projecting conclusions beyond what could be established from the record, and that there was persistent abridgment of due process by the Chancellor. The situation created, unless adequately remedied and clarified, could be inimical to the future appointment and retention of faculty who support unpopular socio-political-economic viewpoints, except those who would forego public awareness of their viewpoints sufficiently to avoid public disfavor. [p. 87]

Committee on Political Discrimination

On December 5, 1980, the Chair of the Committee on Political Discrimination (CPD) reported to the President and Executive Committee of the American Economic Association on the deliberations of that Committee. A majority of four agreed with the conclusion of the Inquiry Panel that there was political discrimination in the nonreappointment of Bohmer. A minority of two did not agree with the conclusion of the Inquiry Panel.

Beliefs vs. Conduct: All Committee members agreed that the CPD properly could investigate and take action on claims that employment was terminated because of the political beliefs of the claimant. There was a difference of opinion, however, whether the Committee's function extended to cases of political "activism" (expressed as conduct, for example, participating in demonstrations, confrontations, and the like).

Although Dumke adduced Bohmer's *conduct* as the grounds for denial of reappointment, the Committee considered the possibility that his perceptions of Bohmer's *beliefs* also afforded a motive for his action. While the Panel Report contains material which might tend to support such an inference, it did not, in the view of the Committee, make a record which would support this as a finding. Indeed, the fact that there are other radical economists at San Diego State (about whose treatment no complaint is being made here) argued strongly against the view that Bohmer's beliefs were the motive for Dumke's action. Consequently, the Committee evaluated the case in terms of Bohmer's conduct as the grounds for denial of reappointment.

In the minority view, the Committee should confine its attention to cases of the more nearly "pure" political-beliefs-type, thus excluding the instant case, since activism is not essential to faculty communication of views, and, moreover, claimants could characterize a wide range of their behavior as "political," thereby inappropriately coming within the purview of the Committee.

The majority view is that cases of the activism type are properly within the jurisdiction of the CPD. To exclude these cases would be to exclude, perhaps, a majority of the cases in which political considerations may play an improper role in personnel decisions. The majority view is that the CPD should invoke its processes to attempt to protect the right of faculty members to engage in lawful political activism. For to do otherwise might imply that faculty members who support unpopular viewpoints are to be protected against political discrimination only if they "... would forego public awareness of their viewpoints sufficiently to avoid public disfavor" (Panel Report, p. 87).

"Compelling Reasons": In ruling that Bohmer would not be reappointed, Dumke overturned the findings and conclusions of all of

the responsible faculty bodies and administrators at San Diego State. All Committee members agreed that the charge to the CPD does not give jurisdiction over academic governance issues in general and that governance issues should enter into the CPD's deliberations only as evidence of political discrimination. Beyond this, there were differences of opinion.

In the minority view, the Panel Report did not establish Dumke's governance actions (whether or not generally acceptable) as evidence of political discrimination and hence the CPD had no cause to raise the question whether Dumke's reasons for his actions should be regarded as "compelling" or otherwise acceptable. More affirmatively, this view holds that administrators in Dumke's position have proper authority to overturn what they regard as the mistaken decisions of faculty bodies and campus administrators, subject to academic statutes. In law, tradition, and customary practice, they are and should be held responsible for their judgments and decisions, by the campus community, trustees, academics, and the larger society.

The majority view notes that, in accord with commonly accepted standards of academic governance (which also appear to have been the standards that had been adopted at San Diego State), Dumke properly could overturn the findings and conclusions of the responsible faculty bodies only for "compelling" reasons. Dumke charged Bohmer with responsibility for a number of on-campus demonstrations. In evaluating this case, the majority felt it important to recognize that all of these events took place after disciplinary proceedings against Bohmer had been invoked and that most of these events took place after an initial notice on nonrenewal of appointment had been given. In the majority view, the only reasonable explanation of Dumke's extreme governance actions was that they were responsive to and actuated by his perceptions of conduct that appears to be clearly political in character. Given this, it was appropriate to raise the question whether the reasons afforded were to be regarded as compelling. The majority agreed with the Panel that Dumke's reasons fell short of being compelling. Consequently, the majority reached the conclusion that Bohmer had been improperly terminated for political reasons.

The report concluded: "In evaluating these positions, it is important to be clear that the majority does not take the extreme view that there can be no compelling reasons in political-activism-type cases for an administrator in Dumke's position to take the action he did. The majority does not endorse disruptive activism. Were the majority persuaded on the record that Bohmer was centrally responsible for events such as the physical invasion of buildings, etc., it would find Dumke's reasons compelling. The majority has not been persuaded of this, however."

AEA Executive Committee

At its March 20, 1981 meeting, the Executive Committee of the American Economic Association voted to accept the report of the Committee on Political Discrimination and endorse the majority position that there was political discrimination in the nonreappointment of Bohmer.

The Executive Committee directed that the actions taken by the Association be reported in the Association's publications. Fuller statements of majority and minority views and copies of the Inquiry Panel report are available upon request.

NOTES

The ninety-fourth annual meeting of the American Economic Association will be held in Washington, D.C., December 28-30, 1981.

The Professional Placement Service will be located at the Sheraton-Washington, Hotel. It will be open from 10:00 A.M. to 5:00 P.M., December 27; 9:00 A.M. to 5:00 P.M., December 28-29; and 9:00 A.M. to 12:00 noon, December 30.

Call for Papers for the 1982 Meetings

Members wishing to give papers or make suggestions for the program for the meetings to be held in New York, December 28-30, 1982, are invited to send their ideas and abstracts to Professor W. Arthur Lewis, The Woodrow Wilson School, Princeton University, Princeton, NJ 08544. Although most of the sessions sponsored by the American Economic Association will consist of invited papers, there will also be several sessions of noneconometric contributed papers, (The sessions of contributed papers will not be published in the *Papers and Proceedings* issue.) Proposals for invited sessions should be submitted as soon as possible. To be considered for the contributed sessions, abstracts of proposed (noneconometric) papers must be received no later than January 15, 1982. Economists wishing to give papers on econometrics or economic theory may submit abstracts to the Econometric Society, which meets with the American Economic Association, and annually schedules a substantial number of contributions.

The International Economic Association is organizing in 1981, 1982, and 1983 various roundtable conferences leading up to a world congress on "Structural Change, Economic Interdependence and World Development." Authors of recent contributions to aspects of the above subject matter are invited to send abstracts of their work to the Secretariat of the IEA (4 rue de Chevreuse, 75006 Paris, France) so that they may be forwarded to the different organizers likely to be interested in their contributions for a roundtable conference or for the Congress. A copy might also be sent directly to the President of the IEA, Professor Victor L. Urquidi, El Colegio de Mexico, Camino al Ajusco No. 20, Mexico 20, D.F., Apartado Postal 20-671, Mexico.

The thirty-eighth conference of the International Institute of Public Finance (Institut International de Finances Publiques) will be held August 23-27, 1982, in Copenhagen. The topic will be Inefficiency in the Public Sector. The Institute invites members of other disciplines to contribute. Write to President, IIPF, Professor Horst Claus Recktenwald, Friedrich-Alexander-Universität Erlangen-Nürnberg, Lange Gasse 20, 8500 Nürnberg, Germany (telephone 0911+5302-2000).

Economists who are strongly oriented toward the humanities, who use humanistic methods in their research, and who will be participating in meetings held outside the United States, Mexico, and Canada that are concerned with the humanistic aspects of their discipline are eligible to apply for small travel grants of the American Council of Learned Societies. Financial assistance is limited to air fare between major commercial airports and will not exceed one-half of projected economy-class fare. Social scientists and legal scholars who specialize in the history or philosophy of their disciplines are eligible if the meeting they wish to attend is so oriented. Applicants must hold a Ph.D. degree or its equivalent, and must be citizens or permanent residents of the United States. To be eligible, proposed meetings must be broadly international in sponsorship or participation, or both. The deadlines for applications to be received in the ACLS office are: meetings scheduled between July and October, March 1; for meetings scheduled between November and February, July 1; for meetings scheduled between March and June, November 1. Please request application forms by writing directly to the ACLS (Attention: Travel Grant Program), 800 Third Avenue, New York, NY 10022, setting forth the name, dates, place, and sponsorship of the meeting, as well as a brief statement describing the nature of your proposed role in the meeting.

The fifteenth Pacific Science Congress will take place February 1-11, 1983, in Dunedin, New Zealand. One section will be "Social Science and Humanities." For further information, write to the Secretary General, P. O. Box 6063, Dunedin North, New Zealand.

The 1982 annual meeting of the Southern Finance Association will be held November 10-12, 1982, at the Atlanta Hilton Hotel, Atlanta, Georgia (in conjunction with the Southern Economic Association). The deadline for receiving paper proposals is February 28, 1982. Further information can be obtained from Professor Bruce D. Fielitz, President, Southern Finance Association, College of Business Administration, Department of Finance, Georgia State University, Atlanta, GA 30303.

Call for Papers: The twelfth annual program of the Financial Management Association will be held at the St. Francis Hotel, San Francisco, California, October 14-16, 1982. It will stress the interrelationship between

theory and practice in financial and investment management. Please send a two-page, single spaced abstract, indicate your interest in organizing a panel discussion, serving as a chairperson or discussant, or your participation interest before February 15 to Rodney L. Roenfeldt, Vice President-1982 FMA Program, College of Business Administration, University of South Carolina, Columbia, SC 29208 (telephone: 803+777-6644).

The P.W.S. Andrews Memorial Essay Prize of £300 is awarded annually for an essay by a young scholar in the field of Industrial Economics and the Theory of the Firm, broadly interpreted. An essay (in English and not exceeding 10,000 words) should be a work of original research by the candidate only, not previously published or awarded any other prize. The winning essay will normally be published in *The Journal of Industrial Economics*. The deadline is December 31, 1981. Address: Miss B. Cox, University House, the University of Lancaster, Bailrigg, Lancaster, LA1 4YW, England.

Miami Beach, Florida will be the site of the fourteenth Atlantic Economic Conference, October 7-10, 1982. Those wishing to present a paper should include a submission fee of $20.00 (U.S.) for each paper along with two copies of a 500 word summary and a separate cover sheet listing: Location of conference to be considered for; Name of author(s); Institution of affiliation; Mailing address of author(s); Phone number of author(s); Number and name of the *JEL* category under which the article primarily belongs. Those wishing to be discussants or chairmen should also submit the above information to John M. Virgo, Program Chairman, Atlantic Economic Conference, Box 258, Worden, IL 62097.

Call for Papers: The second International Symposium on Inventories will be held in Budapest, August 23-27, 1982. The symposium provides a forum for an international exchange of ideas on macro and micro economic questions of inventories, both theoretical and practical. All subjects related to inventories are welcome. Papers are accepted in English, German, and Russian. There will be simultaneous interpretation during the sessions. Applications and further information can be obtained from Dr. Attila Chikan, Karl Marx University of Economics, PF. 489, Budapest, Hungary, H-1828.

The tenth annual Telecommunications Policy Research Conference will be held April 25-28, 1982, in Annapolis, Maryland. Topics will include international competition in telecommunications hardware and services; the social impact of new telecommunications systems on particular sectors of the economy and society as a whole; regulation, deregulation, and reregulation in telecommunications: historical analysis of the policy targets for broadcast and common carrier regulation. For further information, contact Professor Janusz A. Ordover, Department of Economics, New York University, New York, NY 10003.

For the academic year 1982-83, Harvard Law School offers four or five Liberal Arts Fellowships to college and university teachers in the arts and sciences for a year at the Harvard Law School. Holders of the fellowships will have the title of Fellow in Law and... (History, Sociology, Political Science, Economics, etc., depending upon their particular discipline). Fellowship holders will presumably take at least two first-year courses in law, in addition to more advanced courses, and will participate in a joint seminar. The year of study will not count towards a degree. The fellowship grant covers tuition and health fee only. Applications should include a biographical resume (including academic record and list of publications), and two letters of recommendation (mailed directly to the Chairman from the referees). Submit before January 15 to the Committee on Liberal Arts Fellowships, Harvard Law School, Cambridge, MA 02138. There is no special application form.

Donations of books and journals (especially 1970 on) will be forwarded to the library of Makerere University, Kampala, Uganda by USAID. Address material to Books for Uganda, Att. Mr. Norm Green, AFR/RA Room 3325, AID Department of State, Washington, D.C. 20523. Additional information may be obtained from Professor Irving Gershenberg, African Studies Center, 10 Lenox Street, Brookline, Massachusetts 02146.

A new monograph series entitled Contemporary Studies in Energy Analysis and Policy has been established by JAI Press Inc. The series consists of fresh contributions to energy economics that deal with practical problems based on a logically consistent theoretical structure. Research work in the area of energy economic policy and analysis, problems of planning, etc. are the principal subjects to be dealt with. The methodology should be practical in the sense of not being too far removed from application to actual energy economic conditions. They can be both quantitative and qualitative. Manuscript submissions are welcome and should be sent to Professor Noel D. Uri, Department of Economics and Business Management, The Catholic University of America, Washington, D.C. 20064.

Resources for the Future (RFF) announces availability of two Gilbert F. White Fellowships and several RFF Small Grants for the 1982–83 academic year. The

fellowships are for young professionals with doctoral degrees who wish to spend a year in Washington, D.C., working on social or policy problem in the areas of natural resources, energy, or the environment. The stipend is $22,000, plus an allowance for moving expenses up to $1,000. RFF Small grants of up to $30,000 each will be awarded for research on resources, energy, or environmental policy problems by professionals in either the natural or social sciences. (Seven grants of $4,500 to $30,000 were made for 1981–82.) Further information and application forms may be obtained by writing to the Fellowship and Small Grant Programs, RFF, 1755 Mass. Ave., NW, Washington, D.C. 2036. Deadline for completed applications is March 1, 1982. Awards will be announced about April 1, 1982.

The annual meeting of the Southwestern Finance Association will be held March 17-21, 1982, at the Hyatt Regency Hotel, Dallas, Texas.

The Carolina Population Center invites applications for a small number of postdoctoral fellowships for 1982–83 for population research training in the following fields: anthropology, economics, epidemiology, maternal and child health, psychology, and sociology. Postdoctoral programs of the following types will be considered: specialized training in the discipline of the applicant's doctorate for those holding doctorates involving population research training; training in a second discipline for those with doctorates involving population research training; individualized interdisciplinary programs for those with doctorates which may (but need not) involve population research training. Applicants must be U.S. citizens or permanent residents of the United States. The application deadline is February 1, 1982. Direct inquiries to J. Richard Udry, Director, Carolina Population Center, University of North Carolina, Chapel Hill, NC 27514.

The Emory University Law and Economics Center will hold its next L&EC Legal Institute for Economists, June 20-July 3, 1982. Director Henry G. Manne heads the two-week course which provides an intensive introduction to the American legal system, its institutions, research methods and procedures. Fellowships to the Institute provide private rooms, most meals, books, program tuition and group social activities. Travel expenses are not paid. Fellowships include a stipend of $250 for most participants. Send a current curriculum vita and a statement that you plan to attend the entire program if accepted. Application deadline is February 12, 1982. Notification will be made February 19, 1982. Direct applications and questions to Mr. Marc Hoberman, Program Administrator, Emory University, Law and Economics Center, Atlanta, GA 30322. (Telephone 404+329-5768)

The Committee on Institutional Cooperation (CIC) offers twenty-five four-year fellowships to minority students seeking Ph.D. degrees in the social science disciplines to include economics and political science. The fellowships provide full tuition and a stipend of at least $5,000 for each of four years. The deadline for 1982 academic year is January 15, 1982. Details may be obtained from the CIC Minorities Fellowships Program, 111 Kirkwood Hall, Indiana University, Bloomington, IN 47405. Prospective applicants from outside Indiana may call (toll free) 800+457-4420. The fellowships may be used at the following universities: University of Chicago, University of Illinois; Indiana University, University of Iowa, University of Michigan, Michigan State University, University of Minnesota, Northwestern University, Ohio State University, Purdue University, and University of Wisconsin.

The first Time Series Interaction Committee Symposium on the subject of Time Series Analysis of Unequally Spaced Data will be held in the summer of 1982 at Texas A&M University under the direction of Emanuel Parzen. For further information on the activities of the Committee, contact M. Ray Perryman, Center for the Advancement of Economic Analysis, Baylor University, Waco, Texas 76798.

The seventh International Time Series Meeting (ITSM) will be held in Dublin, Ireland, March 15–19, 1982. It will feature invited and contributed papers and discuss recent developments in the theory and practice of time series analysis. Contact Oliver Anderson, ITSM Dublin, 9 Ingham Grove, Lenton Gardens, Nottingham NG7 2LQ, England. (Telephone: National, 0602+708085; International, 44602+708085.)

The International Forecasting Conference (IFC) will be held in Valencia, Spain, May 24–28, 1982. Contributed papers and session chairmen are invited. Editorial collaborators for the *Proceedings* are also needed. There will be emphasis on applications and communication with planners and decision makers. Details may be obtained from Oliver Anderson, IFC Spain, address and telephone noted above for ITSM.

Deaths

Normand R. Noel, associate professor of economics, Providence College, Mar. 27, 1981.

Jane Cassels Record, senior economist, Kaiser Foundation Health Services Research Center, Feb. 8, 1981.

Retirements

Robert T. Collins, professor of economics, University of South Carolina.

Joel B. Dirlam, professor, University of Rhode Island.

William D. Grampp, professor of economics, University of Illinois-Chicago Circle, Sept. 1980.

Tjalling C. Koopmans, Alfred Cowles Professor, economics, Yale University, June 1981.

John Perry Miller, Elizabeth S. and A. Varick Stout Professor, social science and economics, Yale University, June 1981.

Donald W. Paden, professor, University of Illinois-Urbana, Mar. 1, 1981.

John B. Parrish, professor, University of Illinois-Urbana, Aug. 21, 1981.

Lloyd G. Reynolds, Sterling Professor, economics, Yale University, June 1981.

Richard A. Sabatino, professor and chairman, University of Rhode Island.

William H. Wesson, professor of economics, University of South Carolina.

Visiting Foreign Scholars

Emil Claassen, visiting professor of economics, University of South Carolina, summer 1982.

Claude Hillinger, University of Munich: visiting professor, University of Southern California, Jan. 1982.

Hukukane Nikaido, Hitotsubashi University, Tokyo: visiting professor, University of Southern California, Sept. 1981.

Asher Tishler, Tel Aviv University: visiting assistant professor, University of Southern California, Sept. 1981.

Promotions

Gilbert W. Bassett, Jr.: assoicate professor of economics, University of Illinois-Chicago Circle, fall 1980.

Glenn C. Blomquist: associate professor of economics, University of Kentucky, July 1, 1981.

James H. Cassing: associate professor, economics department, University of Pittsburgh, Sept. 1, 1979.

Donald V. Coes: associate professor, University of Illinois-Urbana, Aug. 21, 1981.

William R. Dougan: assistant professor of economics, Dartmouth College, July 1, 1981.

Robert W. Gillespie: professor, University of Illinois-Urbana, Aug. 21, 1981.

Alan L. Gustman: professor of economics, Dartmouth College, July 1, 1981.

Curtis E. Harvey: professor of economics, University of Kentucky, July 1, 1981.

Gerald D. Jaynes: associate professor, Yale University, July 1, 1981.

Michael S. Joshua: director, Bureau of Economic Research and Development, Virginia State University, Apr. 1, 1980.

Arie Kapteyn: associate professor, University of Southern California, Sept. 1981.

M. Ali Khan: professor of economics, The Johns Hopkins University, July 1, 1981.

Laurence J. Kotlikoff: associate professor, Yale University, July 1, 1981.

Kajal Lahiri: professor of economics, State University of New York-Albany, Sept. 1, 1981.

Jerome K. Laurent: professor of economics, University of Wisconsin-Whitewater.

John F. McDonald: professor of economics, University of Illinois-Chicago Circle, Sept. 1981.

James R. Marsden: professor of economics, University of Kentucky, July 1, 1981.

Norman C. Miller: professor, economics department, University of Pittsburgh, Sept. 1, 1980.

Jorge Sanguinetty: associate professor of economics, The American University.

Allen J. Scafuri: assistant professor, Wayne State University, Sept. 1, 1981.

James Smith: associate professor, University of Illinois-Urbana, Aug. 21, 1981.

Houston H. Stokes: professor of economics, University of Illinois-Chicago Circle, Sept. 1981.

Alfred D. Sumberg: associate general secretary, American Association of University Professors, Washington, D.C.

Gilbert S. Suzawa: associate professor, University of Rhode Island.

Leigh Tesfatsion: associate professor, University of Southern California, Sept. 1981.

Thomas Ulen: associate professor, University of Illinois-Urbana, Champaign, Aug. 21, 1981.

Donald M. Waldman: assistant professor, University of North Carolina-Chapel Hill, July 1, 1980.

Laurence M. Weiss: associate professor, Yale University, July 1, 1981.

Administrative Appointments

Ashok Bhargava: chairman, economics department, University of Wisconsin-Whitewater, Aug. 1, 1981.

William C. Brainard: provost, Yale University, July 1, 1981.

Irving Brecher: chairman, economics department, McGill University, June 1981.

J. Ronnie Davis, University of Florida: dean, Western Washington University's College of Business and Economics, July 1981.

Kenneth V. Greene: chairman, economics department, State University of New York-Binghamton, June 1, 1981.

Bhajan S. Grewal: dean, faculty of commerce and economics, James Cook University of North Queensland, Mar. 1, 1981.

Robert S. Holbrook: associate vice president for academic affairs, University of Michigan, July 1, 1981.

Joseph Horton: professor and chairman, Commerce Division, Bellarmine College, Aug. 15, 1981.

Julius Margolis: chairman, economics department, University of California-Santa Cruz, July 1, 1981.

Jacob B. Michaelsen: chairman, board of studies in economics, University of California-Santa Cruz, July 1, 1981.

William S. Rawson: director of graduate studies, University of South Carolina.

Nallapu N. Reddy: chairman, economics department, University of Michigan-Flint, Jan. 1, 1981.

Rosalind Seneca: chairperson, economics department, Drew University, Sept. 1, 1981.

James L. Starkey: chairman, economics department, University of Rhode Island.

Peter O. Steiner: dean, College of Literature, Science and the Arts, University of Michigan, July 1, 1981.

Howard M. Wachtel: chairman, economics department, The American University.

Gordon C. Winston: chairman, economics department, Williams College, July 1, 1981.

Appointments

Nabeel Alsalam, University of California-Los Angeles: assistant professor, economics department, University of Rochester, July 1, 1981.

Richard Berg: assistant professor of economics, University of California-Santa Cruz, July 1, 1981.

Mark C. Berger: assistant professor of economics, University of Kentucky, Sept. 1981.

John P. Bigelow, University of Pennsylvania: assistant professor, Yale University, July 1, 1981.

Nicholas Bruck: assistant professor, department of economics, The American University.

John P. Burkett: assistant professor, economics department, University of Rhode Island.

Ronald Lee Caplan: assistant professor, economics department, Drew University.

Donald C. Cox, Federal Reserve Bank of New York: assistant professor, Washington University (St. Louis) Sept. 1981.

Ali F. Darret: assistant professor of economics, University of Kentucky, Sept. 1981.

Robin A. Dubin, Johns Hopkins University: assistant professor, Wayne State University, Sept. 1, 1981.

Guillermo Estebanez, University of California-San Diego: visiting assistant professor of economics, University of California-Santa Cruz, July 1, 1981.

Michael Fortunato, Howard University: assistant professor of economics, Williams College, July 1, 1981.

Maxwell Fry, University of Hawaii: professor, University of California-Irvine, fall 1981.

Peter Garber: assistant professor, economics department, University of Rochester, July 1, 1981.

John E. Garen, Ohio State University: assistant professor, Wayne State University, Sept. 1, 1981.

David Gordon, University of Chicago: assistant professor, economics department, University of Rochester, July 1, 1981.

John Kevin Green, The University of the South: associate professor, department of accounting, School of Business, East Carolina University, Aug. 1981.

Kristin M. Hallberg, University of Wisconsin: assistant professor of economics, Amherst College, July 1, 1981.

William J. Hausman: associate professor, College of William and Mary, Aug. 1981.

James F. Haynes, Huntsville City Schools: assistant professor of economics, Athens State College, Sept. 1, 1981.

Barry T. Hirsch: visiting associate professor of economics, University of Kentucky, 1981-82.

Linda Lucas Hudgins: assistant professor of economics, University of Notre Dame, 1981-82.

Steven Husted: assistant professor, economics department, University of Pittsburgh, Sept. 1, 1980.

C. Michael Jones, Wesleyan University: assistant professor, Yale University, July 1981.

Shulamit Kahn, Massachusetts Institute of Technology: assistant professor, University of California-Irvine, fall 1981.

Chander Kant: assistant professor, economics department, The American University.

Janet E. Kohlhase, University of Pennsylvania: instructor, economics department, Michigan State University, Sept. 1980.

Tryphon E. Kollintzas: assistant professor, economics department, University of Pittsburgh, Sept. 1, 1980.

Brent G. Kroetch, University of Chicago: assistant professor, economics department, The American University.

Laura B. LaHaye, University of Chicago: assistant professor of economics, University of Illinois-Chicago Circle, Sept. 1980.

Kevin Lang, Massachusetts Institute of Technology: assistant professor, University of California-Irvine, fall 1981.

Leonard P. Lardaro: assistant professor, economics department, University of Rhode Island.

G. S. Laumas: visiting professor of economics, University of Kentucky, fall 1981.

Evelyn B. Lehrer, Northwestern University: assistant professor of economics, University of Illinois-Chicago Circle, Sept. 1980.

Cathy L. McHugh, Stanford University: instructor, University of North Carolina-Chapel Hill, July 1, 1980.

Robert J. McIntyre: visiting associate professor of economics, Dartmouth College, Sept. 1, 1981.

Stanley H. Masters: professor of economics, State University of New York-Binghamton, Sept. 1, 1981.

Subodh Mothur, Massachusetts Institute of Technology: assistant professor of economics, The American University.

Maud Naroll: instructor of economics, Dartmouth College, July 1, 1981.

Abdul-Hameed Naz, International Economic Research and Investment Corporation: professor of economics and management, Elizabeth City State University, North Carolina, Aug. 1981.

Eric R. Nelson, Smith College: assistant professor of economics, Amherst College, July 1981.

Jürg Niehans: visiting professor, department of political economy, The Johns Hopkins University, July 1-Dec. 31, 1981.

Kazuo Nishimura, State University of New York-Buffalo: assistant professor, University of Southern California, Sept. 1981.

Haim Ofek: associate professor of economics, State University of New York-Binghamton, Sept. 1, 1981.

William B. O'Neil, Wisconsin Legislative Council: assistant professor of economics, Amherst College, July 1, 1981.

Douglas R. Ostrom, Dartmouth College: visiting lecturer, economics, Williams College, fall 1981.

Amar Parai, University of Pittsburgh-Johnstown: assistant professor of economics, Case Western Reserve University, Aug. 26, 1981.

Richard Peck, Yale University: assistant professor of economics, University of Illinois-Chicago Circle, Jan. 1982.

Richard G. Price: assistant professor of economics, State University of New York-Binghamton, Sept. 1, 1981.

Nguyen Thanh Quan, University of Detroit: assistant professor, economics department, Case Western Reserve University, Aug. 26, 1981.

Salim Rashid: assoicate professor, University of Illinois-Urbana, Aug. 21, 1981.

Elyce J. Rotella, San Diego State University: associate professor of economics, Indiana University, Aug. 1981.

Kathy A. Ruffing, Social Security Administration: analyst, Projections Unit, Congressional Budget Office, July 13, 1981.

Mark Rush: assistant professor, department of economics, University of Pittsburgh, Sept. 1, 1981.

Joel D. Scheraga, Brown University: assistant professor, Rutgers University-New Brunswick, July 1, 1981.

Juliet Schor, University of Massachusetts: assistant professor of economics, Williams College, July 1, 1981.

William G. Shepherd, University of Michigan: visiting professor of economics, Williams College, spring 1982.

Padmanabhan Srinagesh, University of Rochester: assistant professor of economics, University of Illinois-Chicago Circle, Jan. 1980.

Karen A. Swiderski, Brown University: economist, International Monetary Fund, Oct. 1, 1981.

Paul N. Van de Water, Social Security Administration: chief, Projections Unit, Congressional Budget Office, June 1, 1981.

Sidney Weintraub, University of Pennsylvania: visiting professor of economics, Williams College, spring 1982.

Richard Weisskoff, Iowa State University-Ames: visiting associate professor, economics department, The American University.

W. P. Welch: assistant professor, economics department, University of Pittsburgh, Sept. 1, 1980.

James R. White, Columbia University: visiting assistant professor of economics, Williams College, 1981-82.

John Willoughby: assistant professor, economics department, The American University.

Willard E. Witte, Pennsylvania State University: assistant professor of economics, Indiana University, Aug. 1981.

Glenn Woroch: assistant professor, economics department, University of Rochester, Jan. 16, 1981.

Nicholas C. Yannelis, University of Rochester: assistant professor, Wayne State University, Sept. 1, 1981.

Edward Zabel, University of Rochester: economics department, University of Florida, Dec. 1980.

Leaves for Special Appointments

Lee Alston, Williams College: University of Washington, 1981-82.

Roger Bolton, Williams College: Department of City and Regional Planning, University of Pennsylvania, 1981-82.

James M. Boughton, Indiana University: senior economist, International Monetary Fund, July 1981.

James H. Cassing, University of Pittsburgh: associate professor, department of economics, Australian National University, Sept. 1, 1980-Apr. 30, 1982.

James H. Cobb, Florida State University: associate professor and senior research fellow, Institute of Southern African Studies, National University of Lesotho, July 1, 1981-June 30, 1982.

Asim Erdilek, Case Western Reserve University: policy analyst, International Economic Policy, National Science Foundation, Sept. 1981.

Tatsuo Hatta, The Johns Hopkins University: visiting associate professor of economics, Columbia University, July 1, 1981-June 30, 1982.

Walter C. Labys, West Virginia University: visiting scholar, Energy Lab, Massachusetts Institute of Technology, Aug. 15, 1981-June 15, 1982.

Charles A. Lave, University of California-Irvine: visiting scholar, Massachusetts Institute of Technology.

Youngil Lim, University of Hawaii: Global and Conceptual Studies Branch, International Centre for Industrial Studies, U.N. Industrial Development Organization, Vienna, Austria, 1981-83.

Michael McPherson, Williams College: Institute for Advanced Study, Princeton University, 1981-82.

James L. Murphy, University of North Carolina-Chapel Hill: University of New South Wales, fall 1980.

Steven S. Rosefielde, University of North Carolina-Chapel Hill: Naval Postgraduate School, fall 1980.

John Sheahan, Williams College: Institute for Development Studies, University of Sussex, 1981-82.

Alan A. Walters, The Johns Hopkins University: economic advisor (Second Permanent Secretary to the Prime Minister in No. 10 Downing Street), Jan. 1, 1981-June 30, 1982.

Michael Wattleworth, Williams College: International Monetary Fund, 1981-1982.

Kenneth L. Wertz, University of North Carolina-Chapel Hill: Committee on Taxation, U.S. Congress, 1980-81.

Resignations

Jess Benhabib, University of Southern California: New York University, Sept. 1981.

Robert T. Jerome, Jr., University of Notre Dame: George Mason University, fall 1981.

Gerald H. Kramer, Yale University: California Institute of Technology, June 1981.

David P. Levine, Yale University: University of Denver, July 1, 1981.

David Lee Reinders, Iowa State University: Farmbank Services, Denver.

R. Robert Russell, University of California-San Diego: New York University, Apr. 1, 1981.

Carl P. Simon, University of North Carolina-Chapel Hill, May 17, 1981.

Robin Walther, University of Southern California: Southern California Edison Co., Sept. 1981.

NOTE TO DEPARTMENTAL SECRETARIES AND EXECUTIVE OFFICERS

When sending information to the *Review* for inclusion in the Notes Section, please use the following style:

A. Please use the following categories:

1—Deaths
2—Retirements
3—Foreign Scholars (visiting the USA or Canada)
4—Promotions
5—Administrative Appointments
6—New Appointments
7—Leaves for Special Appointments (NOT Sabbaticals)
8—Resignations
9—Miscellaneous

B. Please give the name of the individual (SMITH, Jane W.), her present place of employment or enrollment: her new title (if any) new institution and the date at which the change will occur.

C. Type each item on a separate 3×5 card and please do not send public relations releases.

D. The closing dates for each issue are as follows: *March*, October 15; *June*, January 15; *September*, April 15; *December*, July 15.

All items and information should be sent to the Assistant Production Editor, *American Economic Review*, Editorial Office, Bunche Hall, University of California, Los Angeles, CA 90024.

NOTICE TO ALL GRADUATE DEPARTMENTS

The December 1982 issue of the *Review* will carry the seventy-ninth list of doctoral dissertations in political economy in American universities and colleges. The list will specify doctoral degrees conferred during the academic year terminating June 1982. This announcement is an invitation to send us information for the preparation of the list.

The *Review* will publish in its December 1982 issue the names of those who will have been awarded the doctoral degree since June 1981 and the titles of their dissertations. Dissertation abstracts are not published, as these are published elsewhere.

By June 30, please send us this information on 3×5 cards, conforming to the style shown below, one card for each individual. Please indicate by a classification number in the right-hand corner the field in which the thesis should be classified. The classification system is that used by the *Journal of Economic Literature* and printed in every issue.

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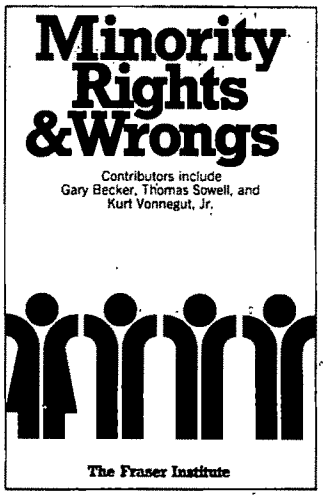

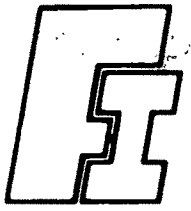

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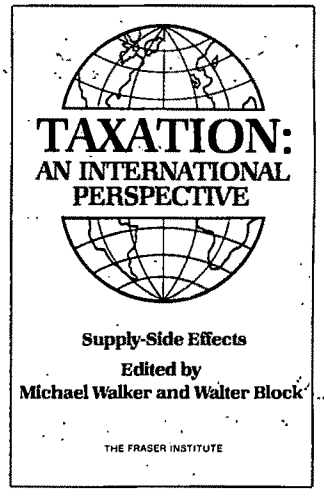

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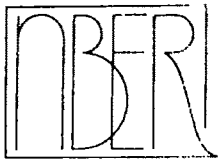

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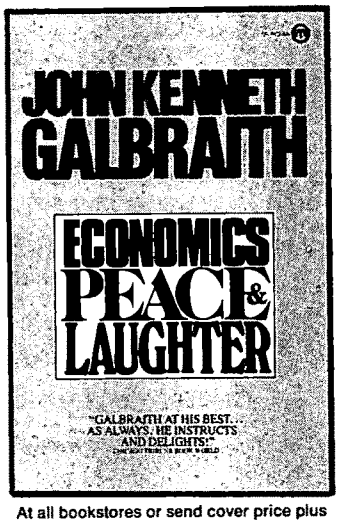

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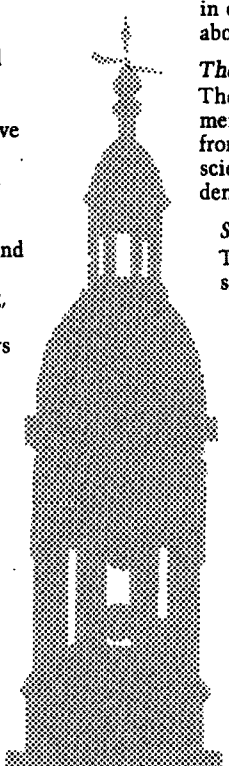

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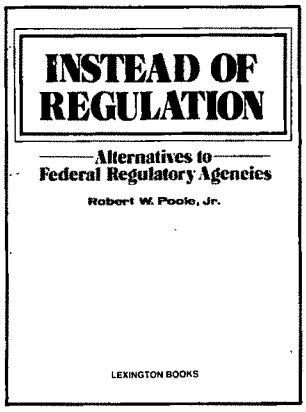

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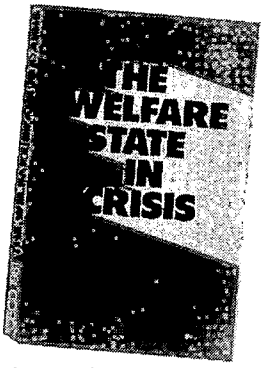

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December 1981

Volume 71, Number 6

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Foreword

This is a special issue of the *American Economic Review*. It contains reprints of three Nobel Memorial Lectures and the material that used to be published separately as a directory of members. The lectures were originally delivered when the authors received the Nobel Prize in Economic Science. They are reprinted here in chronological order. Ragnar Frisch ("From Utopian Theory to Practical Applications: The Case of Econometrics") and Jan Tinbergen ("The Use of Models: Experience and Prospects") were co-winners in 1969, the inaugural year of the prize. John Hicks ("The Mainspring of Economic Growth") and Kenneth Arrow shared the award in 1972. Arrow's lecture and those of other American laureates have been reprinted previously.

This issue also contains biographical information about AEA members and supplementary information about the Association. The biographical material was compiled from questionnaires (cf. facsimile, pages 457–458) mailed to members in April, 1981. If the questionnaire was not returned, existing biographical data or simply name and address are printed. The *Survey* contains the names of all members who were current as of June, 1981.

On behalf of the Association, I wish to express appreciation to Mary L. Winer, our Administrative Director. She planned the project, managed it to completion, and attended to the thousand and one details involved with the publication of the *Survey*.

C. Elton Hinshaw
Secretary

General Information on the Association

History and Objectives

The American Economic Association was organized in 1885 at a meeting at Saratoga, New York, by a small group interested in economics. It was incorporated February 3, 1923. The purposes of the Association as stated in the charter are to encourage economic research, to issue publications on economic subjects, and to encourage perfect freedom in economic discussions. The spirit of these objectives has been maintained throughout the history of the Association.

From 1885 to about 1910, the membership of the Association consisted mainly of college and university teachers of economics. With the growing general interest in the subject of economics after the turn of the century, the Association attracted an increasing number of members from business and professional groups. Today the membership exceeds 18,500. In addition, approximately 6,000 libraries, institutions, and firms subscribe to the quarterly publications of the Association.

Historical highlights of the Association's origin and growth may be found in: "Report of the Organization of the American Economic Association," Publications of the A.E.A., "First Series," 1886, No. 1, March, pages 5–46; "The American Economic Association, 1885–1909, An Historical Sketch," by R. T. Ely, in *Papers and Discussions of the Twenty-second Annual Meeting* (being the twenty-fifth anniversary of the founding of the Association), "Third Series," 1910, No. 1, April, pages 47–94; "The Fiftieth Anniversary of the Founding of the American Economic Association, 1885–1935," in *Papers and Proceedings,* March 1936, pages 141–50, 317–40; "The First Two Decades of the American Economic Association," by A. W. Coats, *American Economic Review,* September 1960, pages 555–74; "The American Economic Association, 1904–29," by A. W. Coats, *American Economic Review,* June 1964, pages 261–85; and "The American Economic Association's Publications, An Historical Perspective," by A. W. Coats, *The Journal of Economic Literature,* March 1969, pages 57–68.

The American Economic Review

The *American Economic Review* was first published in 1911. Each of the regular issues (March, June, September, and December) contains articles and shorter papers on economic subjects. One issue (May) is devoted to the *Papers and Proceedings* of the previous year's annual meeting. Selected papers and discussions of papers presented at the meetings are published along with reports of officers, committees, and representatives.

The Journal of Economic Literature

In 1963, the *Journal of Economic Abstracts* began publication under the auspices of the Association. In 1969 it was expanded into the *Journal of Economic Literature* and became an official publication of the Association distributed to all members. Issues appear quarterly (March, June, September, and December). The journal contains abstracts of articles from foreign and domestic economic periodicals, lists of new books classified according to subject matter, book reviews, and survey or review articles on topics of interest to the profession.

Other Publications

Since 1961 the Association has sponsored preparation of the *Index of Economic Articles,* a cumulative index covering 1886–1976; volumes covering 1977 and 1978 are scheduled for release in 1981. The *Index* is available from Richard D. Irwin, Inc., 1818 Ridge Rd., Homewood, Illinois 60430.

A revised and expanded sixth edition of the *Guide to Graduate Studies in Economics and Agricultural Economics in the United States and Canada* was prepared by the Economics Institute under the auspices of the American Economic Association and the American Agricultural Economics Association. It is available from Richard D. Irwin, Inc., 1818 Ridge Road, Homewood, Illinois 60430.

As a result of the report of its Committee on Hiring Practices, the Association began publication of *Job Openings for Economists (JOE),* a bi-monthly listing of job vacancies, in 1974. Subscriptions are available on an annual basis from the Association office to members of the Association and departments of economics and organizations which list their openings in *JOE.*

National Registry for Economists

The Association works in cooperation with the National Registry for Economists, a national clearinghouse operating out of the Illinois Job Service in Chicago. Persons seeking a position are encouraged to list their availability with the Registry, 40 West Adams Street, Chicago, Illinois 60603.

Annual Meetings

Each year the Association holds a three-day meeting at which time papers are presented at sessions on general economic subjects. A professional placement service functions to assist employers and applicants and begins a day prior to the December meetings. Meetings will be held in Washington, DC, December 28–30, 1981; New York, December 28–30, 1982; San Francisco, December 28–30, 1983; Dallas, December 28–30, 1984; New York, December 28–30, 1985. All members are invited to attend the annual business meeting, which takes place during this period.

Committees with Special Activities and Research Programs

Contributions to the profession are made by the continuing work of the Association's Committee on Economic Education, Committee on the Status of Minority Groups in the Economics Profession, Committee on the Status of Women in the Economics Profession, and Committee on Political Discrimination.

Membership

Anyone interested in becoming a member may apply to the Secretary. The applicant will be enrolled upon receipt of dues and an endorsement of the application by a member of the Association. Details on the 1981 classes of membership and fees are found on inside cover of this *Survey*.

Membership in the Association entitles a person to receive the journals of the Association, including the *Survey of Members*. Members may also participate in and vote at the annual meetings, vote in the election of officers, and participate in a group life insurance program. In addition to the journals, members receive pre-registration materials for the annual meetings and other announcements of special interest.

Subscriptions

Only individuals may become members of the Association. Libraries, institutions, or firms may become subscribers. Subscribers receive the regular publications of the Association unless otherwise indicated, but do not vote in the annual election of officers.

Certificate of Incorporation and Bylaws

OF THE AMERICAN ECONOMIC ASSOCIATION IN EFFECT ON

DECEMBER 31, 1980

Certificate of Incorporation

We, the undersigned, citizens of the United States, and of the District of Columbia, desiring to associate ourselves as a corporation for purposes authorized by Section 599 of the Code of said District, hereby certify:

First: The name of title by which the society shall be known in law is THE AMERICAN ECONOMIC ASSOCIATION.

Second: The time for which it is organized is perpetual.

Third: The particular business and objects of the society are as follows:

1. The encouragement of economic research, especially the historical and statistical study of the actual conditions of industrial life;
2. The issue of publications on economic subjects;
3. The encouragement of perfect freedom of economic discussion. The Association as such will take no partisan attitude, nor will it commit its members to any position on practical economic questions.

Fourth: The number of its trustees for the first year of its existence shall be fourteen.

IN WITNESS WHEREOF we have made and signed the foregoing certificate this third day of February, 1923.

Edward A. Harriman
Percy W. Bidwell
Lewis C. Gray
Francis Walker

The above certificate was duly witnessed before John P. Cage, Notary Public.

Bylaws

I. MEMBERSHIP

1. Any person interested in economic inquiry may, on the nomination of a member, be enrolled in this Association.[1]

2. There shall be six classes of members other than honorary: regular members with the academic rank of assistant professor or lower or with annual incomes of $12,000 or less irrespective of rank, paying the base fee defined below; regular members with the academic rank of associate professor or with annual incomes above $12,000 but not more than $20,000 paying one and one fifth times the base fee; regular members with the academic rank of full professor or with annual incomes above $20,000 paying one and two fifth times the base fee; family members (two or more persons living at the same address, second membership without subscription to the publications of the Association) paying one-fifth of the base fee; junior members (available to registered students for three years only) paying one-half the base fee; and life members comprising those who qualified for life membership by making a single payment of the designated amount prior to January 1, 1976, and exempt from annual fees.[2]

Effective January 1, 1976, the base fee is $25.00 per year. The Executive Committee may increase the dues schedule, including both the base fee and the income brackets for regular members, in proportion to the increase occuring after January 1, 1976 in relevant price and wage indexes.[3]

[1]Original bylaw adopted at the first meeting of the corporation, February 3, 1923.

[2]As amended at the December 29, 1970, annual meeting. Further amended by mail ballot, October 1975 to introduce greater progressivity in dues structure. Further amended by mail ballot, October 1976.

[3]Addition adopted by mail ballot, November 1971. Further amended by mail ballot, October 1975, October 1976, and October 1980.

3. Foreign economists of distinction may be elected honorary members of the Association. The Executive Committee is authorized to determine the number of foreigners to be elected honorary members. Past presidents of the Association and members who have been awarded the Walker Medal shall be Distinguished Fellows. Additional Distinguished Fellows may be elected, but not more than two in any one calendar year from economists of high distinction in the United States and Canada. Candidates for Distinguished Fellowships shall be nominated by the Nominating Committee or the Executive Committee and they shall be elected by the combined vote of the two committees. The Nominating Committee shall solicit and give due consideration to the recommendations of the Committee on Honors and Awards. The Nominating Committee is free to make no nominations in any particular year. However, it is not limited as to the number of candidates it may nominate in any year. Election to Distinguished Fellowship does not preclude election to any office of the Association.[4]

4. Every member is entitled to receive as they appear, the following publications of the Association: the *American Economic Review,* the *Journal of Economic Literature,* and the *Directory of Members.*[5]

II. TRUSTEES

The Board of Trustees shall be composed of the voting members of the Executive Committee.[6]

III. OFFICERS

1. The Association shall have the following officers who shall be elective officers: a President, a President-elect, two Vice-Presidents, and six elected members of the Executive Committee. The terms of office of the six elected members of the Executive Committee shall each be three years, two of the six terms to expire each year. The President-elect elected in any year shall succeed to the presidency in the following year. Each regular term of office shall coincide with the calendar year or a multiple thereof.[7]

2. The Association shall have the following officers who shall be appointed by the Executive Committee: a Secretary, a Treasurer, a Managing Editor of the *American Economic Review,* a Managing Editor of the *Journal of Economic Literature,* and a Counsel. The terms of office of each of these officers shall be three calendar years.[8]

3. The Executive Committee shall consist of the President, the President-elect, two Vice-Presidents, the Secretary, the Treasurer, the two Managing Editors, the two ex-Presidents who have last held office, and six elected members, provided the Secretary, the Treasurer, and the two Managing Editors shall not be entitled to vote in the Executive Committee's meetings.[9]

IV. DUTIES OF OFFICERS

1. The president of the Association shall preside at all meetings of the Association and of the Executive Committee. In case of his disability, his duties shall devolve upon the President-elect and then the two Vice-Presidents in the order of their election, upon the Secretary, and upon the Treasurer.[10]

2. Before October 1 of each year, the President-elect of the Association shall appoint a Nominating Committee for the following year, this Committee to consist of a past officer as Chairman and not less than five other members of the Association. In addition to appointees chosen by the President-elect, the Committee shall include any other member of the Association nominated by petition including signatures and addresses of not less than 2 percent of the members of the Association, delivered to the Secretary before December 1. No member of the Association may validly petition for more than one nomineee for the Committee.

The names of the Committee shall be announced to the membership immediately following its appointment and the membership invited to suggest nominees for the various offices to the Committee. The Nominating Committee for each year shall be instructed to present to the Executive Committee on or before March 31 a nominee for the President-elect and two or more nominations for each other elective office to be filled, except the presidency, all these nominees being members of the Association. The members of the Nominating and Executive Committees shall constitute an Electoral College which shall consider the nominee of the Nominating Committee for the President-elect and select a single candidate for that office. In the voting in the Electoral College each member shall have one vote provided that the number of members of the Nominating Committee present does not exceed the number of members of the Executive Committee present; otherwise,

[4]As amended at the December 30, 1965, annual meeting. Further amended by mail ballot, October 1975 to delete restriction of Executive Committee electing up to a total of 12 additional Distinguished Fellows. Further amended by mail ballot, October 1976 to remove restriction on the number of foreign honorary members and to authorize the Executive Committee to determine the number. Further amended by mail ballot, October 1977 to correct an anomaly.

[5]As amended by mail ballot, June 1974.

[6]Amended by mail ballot, October 1976 to change wording concerning the number of trustees from "less than 14 or more than 15 in number" to "persons elected as the Executive Committee".

[7]As amended by mail ballot and reported to the December 19, 1958, annual meeting and as further amended at the December 30, 1969, annual meeting.

[8]As amended at the December 28, 1968, annual meeting and further amended by mail ballot, October 1976 to renumber and reword.

[9]As amended by mail ballot and reported to the December 1958, annual meeting and further amended by mail ballot, October 1976 to renumber.

[10]As amended at the December 30, 1960, annual meeting. The original bylaw gave the President the duty of preparing the annual program. This provision was superseded by the amendment to Section IV, paragraph 2, adopted at the December 29, 1958, annual meeting, giving that duty to the first Vice-President (changed to President-elect at the December 30, 1960, annual meeting).

the members of the Nominating Committee present shall have fractional votes such that their sum equals the number of members of the Executive Committee present.[11]

The Secretary shall inform all members of the Association of the actions of the Nominating Committee and the Electoral College not later than the June issue of the *American Economic Review.* An additional nomination for any office may be made by petition, delivered to the Secretary by August 1, including signatures and addresses of not less than 6 percent of the membership of the Association for the office of President-elect and not less than 4 percent for each of the other offices. No member of the Association may validly petition for more than one nominee for the Executive Committee, one nominee for Vice-President, and one nominee for President-elect.

The election of officers by the membership shall take place by mail ballot conducted by the Secretary each year. The ballot shall list all nominees alphabetically with indication "nominated by petition" where applicable. Space shall be provided on the ballot for the individual voter's alternative choice for all offices. The Secretary shall mail the ballots to all members as soon as practicable after August 1 and set a deadline for receipts of ballots in the Secretary's office no earlier than October 1 and no later than November 1. The candidates with the highest number of votes for the various offices will be elected. The results of the election shall be certified and announced by the Secretary at the annual business meeting or in the *American Economic Review.*[12]

3. The President-elect shall be responsible for the program for the annual meeting of the year in which he serves. He may at his discretion appoint a Program Committee to assist him.[13]

4. The Secretary shall keep the records of the Association and perform such other duties as the Executive Committee may assign to him.[14]

5. The Treasurer shall receive and have the custody of the funds of the Association, subject to the rules of the Executive Committee.[14]

6. The Executive Committee shall have the control and management of the funds of the corporation. It may fill vacancies in the list of officers, and may adopt any rules or regulations for the conduct of its business not inconsistent with the constitution or with rules adopted at the annual meetings. It shall act as a committee on time and place of meetings and perform such other duties as the Association shall delegate to it. A quorum shall consist of five voting members.[14]

7. The Managing Editors shall, with the advice and consent of the Executive Committee, appoint members of Editorial Boards to assist them. They shall be ex officiis members and chairpersons of their respective Boards, which shall have charge of the publication of the *American Economic Review* and the *Journal of Economic Literature.*[14,15]

8. The office of the corporation for legal purposes shall be at the office of the Counsel in the District of Columbia, and legal process against the corporation may be served on said counsel.[14]

V. ANNUAL MEETING

1. The annual meeting of this corporation shall be held at such time and place as may be determined by the Executive Committee. Notice of such time and place shall be given by publication in the *American Economic Review,* at least three months prior to such meeting.[1,16]

2. A resolution adopted at an annual meeting in which less than five percent of the membership of the Association has voted thereon shall be submitted within ninety days to a vote by mail ballot if a majority of the Executive Committee determines that, because of the nature or consequences of the resolution, all members should have the opportunity to participate in the final decision. Upon such a determination by the Executive Committee, the resolution shall cease to be effective and shall not become effective unless and until approved by a majority of the mail ballots cast. Mail ballots shall be accompanied by (1) a brief statement by the sponsor or sponsors in support of the resolution, (2) a brief statement of the views of the Executive Committee and, if the Committee favors or takes no position on the resolution, (3) a brief statement by a person or persons whom the Committee designates to represent opposing views.[17]

VI. AMENDMENTS

Amendments, after having been approved by a majority of the Executive Committee, may be adopted by a majority of votes cast in a mail ballot.[18]

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[11]As amended by mail ballot and reported to the December 29, 1958, annual meeting and further amended by mail ballot, October 1976 to strike out as Article III, section 2 and incorporate with Article IV, section 2.

[12]As amended by mail ballot, October 1976.

[13]As amended by mail ballot and reported to the December 1970, annual meeting and further amended by mail ballot, October 1976 to number paragraph as #3.

[14]Original bylaw adopted February 3, 1923, and renumbered at the December 29, 1958, annual meeting. Further amended by mail ballot, October 1976 to renumber.

[15]As amended by mail ballot and reported to the December 29, 1958, annual meeting. Further amended by mail ballot, October 1976 to show existence of *Journal of Economic Literature.*

[16]As amended by mail ballot, October 1975 designating as paragraph 1 and further amended by mail ballot, October 1976 to change the annual meeting notice from 10 days to three months.

[17]Added as paragraph 2 of Article V by mail ballot, October 1975.

[18]As amended by mail ballot, October 1976 to limit method for adoption of amendments to mail ballots only.

Articles

From Utopian Theory to Practical Applications: The Case of Econometrics—Ragnar Frisch

The Use of Models: Experience and Prospects—Jan Tinbergen

The Mainspring of Economic Growth—John Hicks

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FROM UTOPIAN THEORY TO PRACTICAL APPLICATIONS: THE CASE OF ECONOMETRICS*

RAGNAR FRISCH**

INTRODUCTION

In this essay on econometrics in its conception and its use in economic planning for the betterment of man's fate, I will try to cover a very broad field.

When talking about the methodology in the particular fields mentioned—about which I am supposed to have a little more than second hand knowledge—I have always found it *utterly inadequate* to focus attention only on these special fields without seeing them in a much broader perspective.

Therefore it was inevitable that I should have to include in the field of vision of this paper also some branches of science where I can only speak as a layman, hopefully as a somewhat informed layman. For whatever blunders I may have made in these fields I must ask for the reader's forgiveness.

So this paper will include by way of introduction some reflections on human intelligence and wisdom (two very different things), and on the nature of natural laws, including some general reflections of a "Kritik der reinen Vernunft"-sort.

I shall try to present my remarks as far as possible without technicalities and mathematical details, because I want to reach the general reader. This I will do even at the risk of presenting some material which may seem trivial to some of my advanced colleagues.

The subsequent sections will make it more tangible what I mean by the above general formulations. At this stage let me only mention a striking manifestation of the difference between intelligence and wisdom: The case of *Evariste Galois* (1811–1832). He was one of the greatest mathematical geniuses that ever lived. His theory of transformation groups laid for instance completely bare the nature of roots of algebraic equations. This is a striking example of supreme intelligence.

But the case of Galois is also a striking example of lack of wisdom. In a clash with political opponents, where also a girl was involved, in his own words "an infamous prostitute" (1) he accepted a duel with pistols. He was not a good shotsman and knew for certain that he would be killed in the duel. Therefore, he spent the night before the duel in writing down at a desperate speed his mathematical testament. Here we find a brilliant expose of his main mathematical ideas. The next day he was shot, and died the following day at the age of 21.

1. THE LURES OF UNSOLVABLE PROBLEMS

Deep in the human nature there is an almost irresistible tendency to concentrate physical and mental energy on attempts at solving problems that *seem to be unsolvable.* Indeed, for some kinds of active people only the seemingly unsolvable problems can arouse their interest. Other problems, those which can reasonably be expected to yield a solution by applying some time, energy and money, do not seem to interest them. A whole range of examples illustrating this deep trait of human nature can be mentioned.

The mountain climber. The advanced mountain climber is not interested in fairly accessible peaks or fairly accessible routes to peaks. He becomes enthusiastic only in the case of peaks and routes that have up to now not been conquered.

The Alchemists spent all their time and energy on mixing various kinds of matter in special ways in the hope of producing *new* kinds of matter. To produce gold was their main concern. Actually they were on the right track in principle, but the technology of their time was not advanced far enough to assure a success.

The alluring symmetry problem in particle physics. Around 1900, when the theory of the atom emerged, the situation was to begin with relatively simple. There were two elementary particles in the picture: The heavy and positively charged PROTON and the light and negatively charged ELECTRON. Subsequently one also had the NEUTRON, the uncharged counterpart of the proton. A normal hydrogen atom, for instance, had a nucleus consisting of one proton, around which circulated (at a distance of $0.5.10^{-18}$ cm) one electron. Here the total electric

*Section IV has been omitted with the consent of the Nobel Foundation.

**Deceased. Lecture R. Frisch delivered in Stockholm, Sweden, June 1970 when he received the Nobel Prize in Economic Science. The article is copyright © the Nobel Foundation 1970. It is published here with permission of the Nobel Foundation.

charge will be equal to 0. A heavy hydrogen atom (deuterium) had a nucleus consisting of one proton and one neutron around which circulated one electron. And similarly for the more complicated atoms.

This simple picture gave rise to an alluring and highly absorbing problem. The proton was positive and the electron negative. Did there exist a positively charged *counterpart* of the electron? And a negatively charged *counterpart* of the proton? More generally: Did there exist a *general symmetry* in the sense that to any positively charged particle there corresponds a negatively charged counterpart, and vice versa? Philosophically and mathematically and from the viewpoint of beauty this symmetry would be very satisfactory. But it seemed to be an *unsolvable problem* to know about this for certain. The unsolvability, however, in this case was only due to the inadequacy of the experimental technology of the time. In the end the symmetry was completely established even experimentally. The first step in this direction was made for the light particles (because here the radiation energy needed experimentally to produce the counterpart, although high, was not as high as in the case of the heavy particles). After the theory of Dirac, the positron, i.e. the positively charged counterpart of the electron, was produced in 1932. And subsequently in 1955 (in the big Berkeley accelerator) the antiproton was produced.

The final experimental victory of the symmetry principle is examplified in the following small summary table.

	Electric Charge		
	+1	*0*	*−1*
Heavy Particles (mass around 1)	PROTON (Unit of mass = $1{,}67.10^{-24}$g)	NEUTRON	
		Antineutron	Antiproton (1955)
Light Particles $\left(\text{mass around } \frac{1}{1849}\right)$	Positron (1932)	Neutrinos	ELECTRON

Note. Incidentally, a layman and statistician may not be quite satisfied with terminology, because the "anti" concept is not used consistently in connection with the electric charge. Since the antiproton has the opposite charge of the proton, there is nothing to object to the term anti in this connection. The difference between the neutron and the antineutron, however, has nothing to do with the charge. Here it is only a question of a difference in spin (and other properties connected with the spin). Would it be more logical to reserve the terms *anti* and the corresponding *neutr* to differences in the electric charge, and use expressions like, for instance *counter* and the corresponding *equi* when the essence of the difference is a question of spin (and other properties connected with the spin)? One would then, for instance, speak of a counterneutron instead of an antineutron.

The population explosion in the world of elementary particles. As research progressed a great variety of new elementary particles came to be known. They were extremely short-lived (perhaps of the order of a microsecond or shorter), which explains that they had not been seen before. Today one is facing a variety of forms and relations in elementary particles which is seemingly as great as the macroscopic differences one could previously observe in forms and relations of pieces of matter at the time when one started to systematize things by considering the proton, the electron and the neutron. Professor Murray Gell-Mann, Nobel prize winner 1969, has made path-breaking work at this higher level of systematization. When will this drive for systematization result in the discovery of *something still smaller* than the elementary particles?

Matter and antimatter. Theoretically one may very precisely consider the existence of the "anti" form of, for instance, a normal hydrogen atom. This anti form would have a nucleus consisting of one antiproton around which circulated one positron. And similarly for all the more complicated atoms. This leads to the theoretical conception of *a whole world* of antimatter. In theory all this is possible. But to realize this in practice seems again a new and now really *unsolvable* problem. Indeed, wherever and whenever matter and antimatter would come in contact, an explosion would occur which would produce an amount of energy several hundred times that of a hydrogen bomb of the same weight. How could possibly antimatter be produced experimentally? And how could antimatter experimentally be kept apart from the normal matter that surrounds us? And how could one possibly find out if antimatter exists in some distant galaxes or metagalaxes? And what reflections would the existence of antimatter entail for the conception of the "creation of the world", whatever this phrase may mean. These are indeed alluring problems in physics and cosmology which—at least today—seem to be *unsolvable* problems, and which *precisely for this reason* occupy some of the finest brains of the world today.

Travelling at a speed superior to that of light. It is customary to think that this is impossible. But is it really? It all depends on what we mean by "being in a certain place". A beam of light takes about two million years to reach from us to the Andromeda nebula. But my thought covers this distance in a few seconds. Perhaps some day some intermediate form of body and mind may permit us to say that we actually can travel faster than light.

The astronaut William Anders, one of the three men who around Christmas time 1968 circled the moon in Apollo 8 said in an interview in Oslo (2): "Nothing is impossible . . . it is no use posting Einstein on the wall and say: Speed of light—but not any quicker . . . 30 nay 20, years ago we said: Impossible to fly higher than 50,000 feet, or to fly faster than three times the speed of sound. Today we do both."

The dream of Stanley Jevons. The English mathematician and economist Stanley Jevons (1835–

1882) dreamed of the day when we would be able to *quantify* at least some of the laws and regularities of economics. Today—since the break-through of econometrics—this is not a dream anymore but a reality. About this I have much more to say in the sequel.

Struggle, sweat and tears. This slight modification of the words of Winston Churchill is admirably suited to characterize a certain aspect of the work of the scientists—and particularly of that kind of scientists who are absorbed in the study of "unsolvable" problems. They pass through ups and downs. Sometimes hopeful and optimistic. And sometimes in deep pessimism. Here is where the constant support and consolation of a good wife is of enormous value to the struggling scientist. I understand fully the moving words of the 1968 Nobel prize winner Luis W. Alvarez when he spoke about his wife: "She has provided the warmth and understanding that a scientist needs to tide him over the periods of frustration and despair that seem to be part of our way of life" (3).

2. A PHILOSOPHY OF CHAOS. THE EVOLUTION TOWARDS A MAMMOTH SINGULAR TRANSFORMATION

In the The Concise Oxford Dictionary (4)—a most excellent book—"philosophy" is defined as "love of wisdom or knowledge, especially that which deals with ultimate reality, or with the most general causes and principles of things."

If we take a bird's eye-view of the range of facts and problems that were touched upon in the previous section, reflections on the "ultimate reality" quite naturally come to our mind.

A very general point of view in connection with the "ultimate reality" I developed in lectures at the Institut Henri Poincaré in Paris in 1933. Subsequently the question was discussed in my Norwegian lectures on statistics (5).

The essence of this point of view on "ultimate reality" can be indicated by a very simple example in two variables. The generalization to many variables is obvious. It does not matter whether we consider a given deterministic, empirical distribution or its stochastic equivalence. For simplicity consider an empirical distribution.

Let x_1 and x_2 be the values of two variables that are directly observed in a series of observations. Consider a transformation of x_1 and x_2 into a new set of two variables y_1 and y_2. For simplicity let the transformation be linear, i.e.

$$(2.1)\quad \begin{aligned} y_1 &= b_1 + a_{11}x_1 + a_{12}x_2 \\ y_2 &= b_2 + a_{21}x_1 + a_{22}x_2 \end{aligned}$$

The b's and a's being constants.

The matrix

$$(2.2)\quad \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$$

is the Jacobian of the transformation, as it appears in this linear case.

It is quite obvious—and well known by statisticians—that the *correlation coefficient* in the set (y_1y_2) will be different from—stronger or weaker than—the correlation coefficient in the set (x_1x_2) ("spurious correlation"). It all depends on the numerical structure of the transformation.

This simple fact I shall now utilize for my reflections on an "ultimate reality" in the sense of a theory of knowledge.

It is clear that if the Jacobian (2.2) is *singular,* something important happens. In this case the distribution of y_1 and y_2 in a (y_1y_2) diagram is at most one-dimensional, and this happens *regardless* of what the individual observations x_1 and x_2 are—even if the distribution in the (x_1x_2) diagram is a completely chaotic distribution. If the distribution of x_1 and x_2 does not degenerate to a point but actually shows some spread, and if the transformation determinant is of rank 1, i.e. the determinant value being equal to zero but not all its elements being equal to zero, then all the observations of y_1 and y_2 *will lie on a straight line* in the (y_1y_2) diagram. This line will be parallel to the y_1 axis if the first row of the determinant consists exclusively of zeroes, and parallel to the y_2 axis if the second row of the determinant consists exclusively of zeroes. If the distribution of x_1 and x_2 degenerates to a point, or the transformation determinant is of rank zero (or both) the distribution of y_1 and y_2 degenerates to a point.

Disregarding these various less interesting limiting cases, the essence of the situation is that even if the observations x_1 and x_2 are spread all over the (x_1x_2) diagram in any way whatsoever, for instance in a purely chaotic way, the corresponding values of y_1 and y_2 will lie on a straight line in the (y_1y_2) diagram when the transformation matrix is of rank 1. If the slope of this straight line is finite and different from zero, it is very tempting to interpret y_1 as the "cause" of y_2 or vice versa. This "cause", however, is not a manifestation of something intrinsic in the distribution of x_1 and x_2, but is only a human *figment,* a human *device,* due to the special form of the transformation used.

What will happen if the transformation is not exactly singular but only *near* to being singular? From the practical viewpoint this is the crucial question. Here we have the following proposition:

(2.3) Suppose that the absolute value of the correlation coefficient r_x in (x_1x_2) is not exactly 1. Precisely stated, suppose that

$$(2.3.1)\quad 0 \leqslant |r_x| < 1-\epsilon \quad \text{where } 0 \leqslant \epsilon < 1.$$

This means that ϵ may be chosen as small as we desire even exactly 0, but it must not be exactly 1. Hence $|r_x|$ may be as small as we please even exactly 0, but not exactly 1.

Then *it is possible* to indicate a nonsingular transformation from x_1 and x_2 to the new variables y_1 and y_2 with the following property: However small we choose the positive, but not 0, number δ, the correlation coefficient r_y in $(y_1 y_2)$ will satisfy the relation

$$(2.3.2)\ |r_y| \geqslant 1-\delta \qquad 0 < \delta \leqslant 1$$

Whatever the actual distribution of $(x_1 x_2)$ may be, provided only that it satisfies (2.3.1). The nature of the transformation to be chosen will, of course, depend on the previous choice of ϵ and δ. But to any such choice it is possible to indicate a nonsingular transformation with the specified properties.

Briefly expressed in words this means the following:

(2.3.3) Suppose that the distribution of $(x_1 x_2)$ is unknown and arbitrary with the only proviso that it shall not degenerate into a straight line (as expressed by (2.3.1) where we may choose ϵ as small as we please, even exactly 0). We can then indicate a nonsingular linear transformation of the variables x_1 and x_2 which will produce *as strong a correlation in $(y_1 y_2)$ as we please.* (This is expressed in (2.3.2) where we may choose δ as small as we please, however different from 0.)

I have said that it is possible to indicate a nonsingular transformation with the specified properties. This is true, but the smaller we have chosen ϵ and δ the *nearer to singularity* we must go in order to make the linear transformation such as to have the specified properties.

Now let us *reverse* the viewpoint and assume that y_1 and y_2 are directly observed, perhaps with a strong correlation. It seems that we have no way of excluding the possibility that the observed variables y_1 and y_2 are *in fact* derived from an essentially chaotic distribution of two variables x_1 and x_2. More generally: Perhaps there are many x's and y's, and more x's than y's, and consequently a matrix of transformation from the x's to the y's, whose rank is at most equal to the number of the y's. How could we then exclude the possibility that the chaotic world of the x's is "the ultimate reality"?

What would the *transformation* mean in this case? For one thing it would express the present status of our *sense organs* as they have emerged after a long development over time.

It is quite clear that the chances of survival of man will be all the greater the more man finds *regularities* in what seems to him to be the "outer world". The survival of the fittest will simply eliminate that kind of man that does not live in a world of regularities. This development over time would work partly unconsciously through the biological evolution of the sense organs, but it would also work consciously through the development of our experimental techniques. The latter is only an extension of the former. In principle there is no difference between the two. Indeed, science too has a constant *craving for regularities.* Science considers it a triumph whenever it has been able by some partial transformation here or there, to discover new and stronger regularities. If such partial transformations are piled one upon the other, science will help the biological evolution towards the survival of that kind of man that in the course of the millenniums is more successful in *producing* regularities. If "the ultimate reality" is chaotic, the sum total of the evolution over time—biological and scientific—would tend in the direction of producing a mammoth singular transformation which would in the end place man in a world of regularities. How can we possibly on a scientific basis exclude the possibility that this is really what has happened? This is a crucial question that confronts us when we speak about an "ultimate reality". Have we *created* the laws of nature, instead of *discovering* them? Cf. Lamarck vs. Darwin.

What will be the impact of such a point of view? It will, I believe, help us to think in a *less conventional way.* It will help us to think in a more advanced, more relativistic and less preconceived form. In the long run this may indirectly be helpful in all sciences, also in economics and econometrics.

But as far as the concrete day to day work in the foreseeable future is concerned, the idea of a chaotic "ultimate reality" may not exert any appreciable influence. Indeed, even if we recognize the possibility that it is evolution of man that in the long run has *created* the regularities, a pragmatic view for the foreseeable future would tell us that a continued search for regularities—more or less according to the time honoured methods—would still be "useful" to man.

Understanding is not enough, you must have compassion. This search for regularities may well be thought of as the essence of what we traditionally mean by the word "understanding". This "understanding" is one aspect of man's activity. Another—and equally important—is a vision of the *purpose* of the understanding. Is the purpose just to produce an intellectually entertaining game for those relatively few who have been fortunate enough through intrinsic abilities and an opportunity of top education to be able to follow this game? I, for one, would be definitely opposed to such a view. I *cannot be happy* if I can't believe that in the end the results of our endeavours may be utilized in some way for the betterment of the little man's fate.

I subscribe fully to the words of *Abba Pant,* former ambassador of India to Norway, subsequently am-

bassador of India to the United Arab Republic, and later High Commissionar of India to Great Britain: *"Understanding is not enough, you must have compassion."* (6).

3. A BRIEF SURVEY OF THE DEVELOPMENT OF ECONOMICS IN THE LAST CENTURY

Turning now to the more specifically economic matters, it is inevitable that I should begin by making a brief survey of the development of economics in the last century.

In the middle of the 19th century John Stuart Mill (1806–1873) in his famous work "Principles of Economics" said that so far as general principles are concerned the theory of value and price was now completely elaborated. There was nothing more to add, he said, neither for himself nor any other author. To us with our relativistic view on knowledge and the development of science, it is difficult to understand that such a statement could be made. But to the generation that lived at that time these words by Mill appeared to be very close to the truth. In Mill's "Principles" the ideas of Adam Smith (1723–1790), David Ricardo (1772–1823) and Thomas Robert Malthus (1766–1834) had been knit together into an organic, logically and seemingly complete whole.

Subsequent developments have thoroughly denounced Stuart Mill's words. Two break-throughs have emerged in economic theory since the time of Stuart Mill.

The classical theory of value—as we find it streamlined in Stuart Mill—was essentially a theory of production costs based on the thinking of the private entrepreneur. The entrepreneur will think about as follows: "If I could only cut my selling price I would be able to draw the customers to me. This, however, is also the way my competitors think. So, there emerges a sort of gravitational force that pulls prices down. The cost of production is so to speak the solid base on to which the prices fall down and remain. Hence the cost of production is "the cause" of prices. This general viewpoint the classical economists applied with great sagacity to a whole range of commodities, to the relation between wages and profits and to the theory of international prices etc.

This theory contains, of course, an irrefutable element of truth. But it is too simple to give even a crude presentation of the forces at play. The economic process is an *equilibrium* affair where both technological and subjective forces are at play. The subjective element was nearly left out by the classicists.

On this point economic theory was completely renewed in the years between 1870 and 1890 when a number of Austrian economists headed by Karl Menger (1840–1921) undertook a systematic study of the *human wants* and their place in a theory of prices. Similar thoughts were expressed also by the Swiss Leon Walras (1834–1910) and the Englishman Stanley Jevons (1835–1882). This was the first break-through since Stuart Mill.

The Englishman Alfred Marshall (1842–1924) subsequently did much to combine the subjective veiwpoint and the cost of production viewpoint. This led to what we now usually speak of as the neo-classical theory.

Neither the classicists nor the neo-classicists did much to *verify* their theoretical results by *statistical* observations. The reason was partly that the statistics were poor, and partly that neither the classical nor the neo-classical theory was built out with the systematic statistical verification in view. The architectural plan of the theory had so to speak not made room for this verification. This fact was criticized by the German historical school under the leadership of Gustav Schmoller (1838–1917) and by the American institutionalists. These schools, however, had an unfortunate and rather naive belief in something like a "theory-free" observation. "Let the facts speak for themselves". The impact of these schools on the development of economic thought was therefore not very great, at least not directly. Facts that speak for themselves, talk in a very naive language.

In the first part of the 20th century the picture changed. Partly under the influence of the criticism of the historical school and the institutionalists the theoreticians themselves took up a systematic work of building up the theory in such a way that the theory could be brought in immediate contact with the observational material. One might say that from now on economics moved into that stage where the natural sciences had been for a long time, namely *the stage where theory derives its concepts from the observational technique, and in turn theory influences the observational technique.*

For the first time in history it now seemed that the work on the theoretical front in economics—now to a large extent mathematically formulated—and the work on the outer descriptive front should converge and support each other, giving us a theory that was elaborate enough to retain the concrete observational material, and at the same time a mass of observations that were planned and executed with a view to be filled into the theoretical structure.

Of course, there had been forerunners for such a combination of economic theory, mathematics and statistics even earlier. It was represented by such men as Johan Heinrich von Thunen (1783–1850), Augustin Cournot (1801–1877), A. J. Dupuit (1804–1866) and Hermann Heinrich Gossen (1810–1858). But from the first part of the 20th century the movement came in for full. This was the beginning of the econometric way of thinking. And this is what I would call the second break-through since Stuart Mill.

A crucial point in this connection is the quantification of the economic concepts, i.e. the attempts at making these concepts measurable. There is no need to insist on what quantitative formulation of concepts and relations has meant in the natural sciences. And I would like to state that for more than a generation it has been my deepest conviction that the attempted quantification is equally important in economics.

The quantification is important already at the level of *partial* analysis. Here one has studied the demand for such important commodities as sugar, wheat, coffee, pig iron, American cotton, Egyptian cotton, etc.

And the quantification is even more important at the *global* level. Indeed, at the global level the goal of economic theory is to lay bare the way in which the different economic factors act and interact *on each other* in a highly complex system, and to do this in such a way that the results may be used *in practice* to carry out in the most effective way specific desiderata in the steering of the economy.

As long as economic theory still works on a purely qualitative basis without attempting to measure the numerical importance of the various factors, practically any "conclusion" can be drawn and defended. For instance in a depression some may say: A wage reduction is needed because that will increase the profits of the enterprises and thus stimulate the activity. Others will say: A wage increase is needed because that will stimulate the demand of the consumers and thus stimulate activity. Some may say: A reduction of the interest rate is needed because this will stimulate the creation of new enterprises. Others may say: An increase of the interest rate is needed because that will increase the deposits in the banks and thus give the banks increased capacity of lending money.

Taken *separately* each of these advocated measures contains *some particle* of truth, taken in a very partial sense when we only consider *some* of the obvious direct effects, without bothering about indirect effects and without comparing the relative strengths of the various effects and countereffects. Just as one would say: If I sit down in a rowing boat and start rowing in the ordinary way, the boat will be driven *backwards* because of the pressure exerted by my feet in the bottom of the boat.

In a global analysis that shall be useful for practical applications in economic policy in the nation as a whole, the gist of the matter is to study the relative strengths of all relevant effects and countereffects, hence the need for quantification of the concepts.

This perhaps is the most general and most salient formulation of the *need* for econometrics. How far we would be able to go in this direction was of course another question. But at least the attempt had to be made if economics were to approach the state of an applied science.

It goes without saying that econometrics as thus conceived does not exhaust all the contents of economics. We still need—and shall always need—also broad philosophical discussions, intuitive suggestions of fruitful directions of research, and so on. But this is another story with which I will not be concerned here (7). Let me only say that what econometrics—aided by electronic computers—can do, is only to push forward by leaps and bounds the line of demarcation from where we *have to* rely on our intuition and sense of smell.

4. SOME HISTORICAL NOTES ON THE FOUNDING OF THE ECONOMETRIC SOCIETY

This section has been omitted from this reprint.

5. TYPES OF ECONOMETRIC MODELS AS SEEN FROM AN ADVANCED VIEWPOINT TODAY

It is out of the question in this short expose to give a systematic presentation of the problems and methods of econometrics in its modern form. One gets an idea of the broadness of the field by throwing a glance at the program of the Second World Congress of The Econometric Society to be held in Cambridge, England 7–14 September 1970. Here there are a total of 46 precisely defined sessions with a total of 64 organizers of these sessions. The attendance is expected to be between 500 and 1000. (In the first European meeting in 1931 some twenty persons were present.)

What I can do here is to give a survey of types of econometric models at the national level and an example of how one selected problem may be handled.

Some general remarks on types of econometric models at the national level.

The list of variables and the equations and/or bounds that are introduced, constitute the *core* of the model. It may be linear or non-linear.

In addition to the core one may or may not introduce a preference function, that is a function whose maximization defines the goal of the decisions that might be studied through the model. With a preference function it becomes possible to say that one alternative constellation of the values of the set of variables is *better* than another and it might even be possible to proceed to determining an optimal solution. Otherwise the model is only a *purely descriptive one,* that can be used to produce a sample of alternative constellations, or to answer questions of the type: "What will happen if . . .".

In all cases the model may be either static (i.e. connecting only variables at the same point of time), or dynamic (i.e. connecting variables at different points of time). The *recurrent* model, based on a fixed strategy, is a special case of a dynamic model. A moving (rolling) decisional model based on the concept of already-committed-to variables is better adapted for practical applications, I believe.

In all cases the model may be either deterministic or stochastic.

According to the nature of the core and the nature of the preference function the types of models may be classified in the 2 X 3 divisions of tab. (5.1). Most models in actual use at the national level are at present of the simplest types listed in this table. Some additional explanations of the various cases are given in tab. (5.2)

The preference function

A common misunderstanding regarding the preference function is due to a lack of distinguishing between *targets* (i.e. specific values of some selected variables) which one will try to *realize,* and the use of a *preference function,* and also due to a lack of distinguishing between the free and the reduced form of the preference function. It is said that the decision maker at the national level (the responsible political authority) is not able to understand the meaning of the core. Therefore he cannot formulate targets or define a preference function.

These objections vanish if the expert approaches the decision maker in the appropriate way. I have reached this conclusion not only on theoretical grounds but also because of my practical experiences.

One way to approach the decision maker is through *interview questions.* It is well known that people will not always behave in an actual situation exactly in the way they *said* in an interview question that they *would* behave in such and such a situation. But still, I think, it remains that valuable information may be obtained through interview questions, provided the questions are wisely formulated in a *conversational manner,* and not simply carried out by some youngster in the opinion poll trade. I have worked out a rather elaborate technique for such conversational interviews to be carried out by the econometric experts. And I have had the good fortune to test this out in conversations with high-ranking politicians both in developing countries and in industrially developed countries. I have found that it is surprising how far one can reach in this field when the conversation is wisely steered.

Essential points in this connection are: (I) To use the free form—the Santa Claus form—of the preference function. (II) To assure that the interviewed person rids his mind completely of any preconceived (and in many cases erroneous) ideas he might have on the nature of the core, and hence rid his mind of whether it is actually possible to *realize* the alternatives involved in the interview questions. (III) To assure that the interviewed person has rid his mind completely of any possibility of trading in the market any of the alternative situations which are hypothetically offered to him in the interview questions.

The interview approach to the preference function is only a *first stage* in an iterative process which in each step proceeds by an optimal solution of the model. For further details regarding these questions see the section on the transition towards economic planning.

Another misunderstanding which we sometimes hear, is this: It is said that there are *many different* systems of preferences. It is impossible to choose between these systems. Therefore the concept of preference function cannot be used in connection with national models. This is one of the biggest pitfalls in the discussion of this matter. Differences of opinion, of course, there are. One social group may have one type of preference and another social group may have other preferences, and different persons may have different preferences and even the same person may have different preferences at different points of time. All this is, of course, true. But the problem of settling differences of opinion *is not a special problem of econometrics.* It is a general problem of human behaviour and opinions. And there exists a machinery for settling such differences. This machinery is simply the political system of the country. This political system—whatever it may be—is just invented in order to settle such differences. What we have to do as econometricians is to apply this very system for the *formalization* of the preferences to go with our models. Thus the preference function as it appears in our models is an expression for the preferences of *the decision making authority,* whatever this authority may be. The preference function in the model must not be confounded with a general "Welfare function" in the sense of welfare theory.

It is not the task for us as econometricians and social engineers to go into a detailed discussion of the political system. Somewhere in the hierarchy of sciences a line of demarcation has to be drawn. And here is where we find the line of demarcation for the econometric planner. As *citizens* we are, of course, allowed to work for any political system which we think is just and effective. I, for one, would like to work for a system that really deserves the name democracy, but this is another story. Compare the beginning of section 6.

Still another point must be clarified. Sometimes we hear the suggestion that instead of going to the trouble of discussing preferences, we ought to leave it to the experts to put on the table of the politicians a number of *alternatives* for the development path of

Tab. (5.1). Condensed table of types of econometric models at the national level

		No preference function	*The free form of the preference function* The gross form. The Santa Claus form: Which one of some specified few alternatives would you choose, *if* you had a choice? Not necessary to understand the core in order to answer such questions.	*A reduced form of the preference function* Only understandable in terms of the core: The preference function expressed in terms of a set of variables equal in number to the number of degrees of freedom of the core. Mathematically speaking several reduced forms might (and in general will) exist. The choice of one particular reduced form is a practical question.
The core may be of the following two kinds:	*The Institutionally Stable Core* (or shorter: the stable core) Those equations and/or bounds which we *have to accept* if we confine the analyses to the institutional and political setting which it is out of the question to change within the time horizon of the analyses. For details see tab. (5.2). Can also be termed the *obligatory core* or the *obligatory conditions,* or again the conditions that are invariant under a change in the *facultative* conditions.	*The purely descriptive stable model* Leads to the concept of *dependent* (endogenous) and *free* (exogenous) variables. The number of the free variables is equal to the number of degrees of freedom of the core. The concept of *targets* cannot be derived from the model. The only legitimate use of this kind of model is for presenting a sample of *alternative* constellations of the economy, or for answering questions of this sort: What will happen if . . . ? Even such limited uses of the model may have considerable practical importance.	*The free form of the preference function as applied to a stable core* The free form of the preference function is particularly useful when forming interview questions to the responsible politicians. In principle the complete knowledge of the free form is sufficient to formulate an optimalization problem. The expert will then often transform the free form to a reduced form because he finds this convenient.	*A reduced form of the preference function as applied to the stable core* This case is both computationally and for practical uses highly important. It leads to the concept of the *stable core optimal constellation.* it will as a rule not be the final practical optimum, but will be used for comparison purposes. An interesting figure is the amount by which the stable core optimum preference value *is superior* to the value of the preference function which is obtained through any institutional and political system different from that which defines the stable core.
	The Institutionally Sensitive Core (or shorter: the sensitive core) Equations and/or bounds some of which are sensitive to such institutional and political changes, that might be considered within the time horizon of the analyses. When comparing the effects of such institutional or political changes, it is necessary to have a stable core as a fixed point of reference.	*The purely descriptive sensitive model* Similar to the purely descriptive stable model with the difference that target setting now becomes still more arbitrary. The conclusions drawn from this type of model will as a rule be statistically more uncertain than in the stable case because now many of the data are difficult to fix numerically.	*The free form of the preference function as applied to a sensitive core* Same as above but now the free form of the preference function may contain a greater number of variables. Statistical difficulties of the same sort as mentioned in the case to the left, and mathematical difficulties as mentioned in the case to the right.	*A reduced form of the preference function as applied to a sensitive core* In this case, and in this case only, the concept of targets can be derived from the model provided an optimal solution has been attempted. Mathematical difficulties in explicit search for the optimum constellation of the institutional parameters in a given institutional set-up may be circumvented by arranging institutional games. If so, the games must be defined so as to assure comparability between game results and the stable core optimum. Particularly important in a search for the *optimal institutional set-up.*

Tab. (5.2). Some details regarding the structure of the institutionally stable model.

The institutionally stable core
(The obligatory conditions)

A. Definitional equations and bounds.
B. Technological equations and bounds.
C. Such behaviouristic equations and bounds which we *have to* accept within the time horizon of the analyses.

The equations and bounds ABC can also be described as relations which are *invariant* under such changes of the institutional and administrative structure which might be possible within the time horizon. A change which only consists in changing (within prescribed bounds) certain *parameters* (tax rates for instance) characterizing the structure, will not be considered as changing the structures itself *provided* these parameters are counted among the authorized variables.

(In distinction to an obligatory core we may speak of an institutionally and administratively facultative core, i.e. conditions that are not obligatory, see Note below to the right).

The number of degrees of freedom of the core is the number of authorized variables minus the number of independent *equations* in the core. A *bound* cannot influence the number of degrees of freedom of the core *except* in the limiting case where an upper bound is equal to the corresponding lower bound. The two bounds in question may be bounds on a single variable or it may be bounds on a more or less complicated function of the variables. This limiting case is equivalent to the introduction of one more equation, and should be counted as such. The number of degrees of freedom is further discussed in ref. (11).

Shifting from one set to another set of variables that are to be considered as *Government controlled,* does not change the core but it may need an additional *transmission analysis.* See ref. (11b).

If to this core we add a preference function, we get an institutionally stable *decision model.* The preference function does *not* influence admissibility.

Preferences expressed by *conditions* instead of by a preference *function* might influence admissibility. Compare pp. 113–124 of ref. (11). The terms "selection" and "structure" are there used in the same sense as "institutionally stable" or "obligatory" here.

This core gives rise to the institutionally *admissible region,* i.e. the set of points (in the space of the authorized variables) that are *compatible* with the equations and bounds in the institutionally stable core. The dimensionality of the admissible region is equal to the number of degrees of freedom in the core (depending only on the number of variables and on the number of independent equations) but its size and content and its borders depend on the bounds.

Admissibility depends only on the core, not on the preference function.

Note. The relations among the core, the admissibility region and the preference function in the institutionally sensitive case, are in principle similar to those in tab. (5.2), but now not all the equations and bounds are obligatory, but may be chosen differently according to political inclinations.

the nation's economy, and ask the politicians to choose among these alternatives. This may be a defendable procedure if the number of meaningful alternatives is *very small* and if we can trust the experts not to smuggle their *own personal preferences into the choice of alternatives.* Ref. (11c).

Even if we could trust the experts, the listing of alternatives would be impossible in an advanced form of planning. Indeed, in economic political discussions there is a nearly infinite number of specific questions that may be asked. Besides the ones mentioned in section 3 consider for instance these: "Should we build a road between points A and B in the country?", "Should we promote investments that will give employment to many people, or should we on the contrary promote such investments which will save labour?", "Should we aim at a high rate of increase of the gross national product, or should we put more emphasis on a socially justified distribution of it?", "Should we aim, above all, at keeping the price level under control?", "Or should we sacrifice the stability of the price level and put more emphasis on the increase of the gross national product (in real terms)?", "Should we sacrifice a part of the increase of the total gross national product in order to be able to increase the living standards of one specific social group, say fishermen or industrial workers?", "Should we put more emphasis on things that have up to now not been included in the statistical concept of the gross national product? For instance, should we try to avoid air-pollution and all the kinds of intoxications that may be caused by refuse and waste (a problem that must be studied in its *totality* as a problem of *circulation of matter* in society, much in the same way as we study interindustry relations in an input-output table)?", "Should we assess economic value to an undisturbed nature?" etc.

If we should ask the experts to produce a list of feasible alternatives for the development path of the economy, a list that would be comprehensible enough to cover even very approximately all these various specific questions, the list of possible development paths would have to contain millions and millions of alternatives. The number of alternatives would multiply by cross classification.

Such a list is impossible for the simple reason that the experts would be physically unable to analyse and present all these alternatives, and even if all the alternatives could be analysed and put on the table of the politicians, the politicians would be absolutely drowned in information. They would not know where to start and where to end in discussing which alternative to choose. On the electronic computer one speaks of "information death" when one has made the mistake of letting the computer print out too many of the intermediate results. The poor politicians would suffer a similar information death if they found on their table a hypothetical list of the millions and millions of feasible development paths.

In rational economic planning there is no other possibility than to start in patiently on a discussion of the preference function. To begin with the model would have to be heavily aggregated, but as experience is gained, more details would be included.

Finally a warning should be made against one very simple (and therefore very popular) procedure. A large number of references to such simple procedures could be given. Suffice it here by way of example to refer to (12). The unsatisfactory procedure consists in the following: One starts by *guessing* at the probable growth rate of gross national product in future years. And from this guess one tries to estimate through the use of input-output analyses, national accounts etc. what the development of the various production sectors, consumption etc. will be. This is unsatisfactory for at least three reasons: (I) The growth rate depends essentially on what *decisions* are made regarding the steering of the economy. Guessing at the growth rate therefore implies a guess regarding the economic policy that will be followed in the years to come. (II) Even if the growth rate is given, it does *not* follow what the development of the various sectors or consumption etc. will be. The economy has many more degrees of freedom than just one. (III) How can one assert that the growth rate guessed at is the *optimal* one, i.e. the growth rate that corresponds best to the policy makers' preferences? The growth rate is indeed not a datum but a *consequence* of an optimal solution, with all the intricacies connected with the determination of that optimum.

So much for some general points of principle. In the next section I shall discuss some practical questions connected with the transition towards economic planning at the national level.

6. THE TRANSITION TOWARDS ECONOMIC PLANNING AT THE NATIONAL LEVEL

Any econometrician who wants to see practical application of his science, will be highly concerned with applications to economic planning at the national level.

Economic planning the basis for efficiency and a living democracy

I will give my personal views in this matter. I stress the aspect of efficiency as well as the aspect of a living democracy. The problem I am driving at is more ambitious than just to increase the long-term average growth rate of gross national product. My purpose is to make economic planning at a high aspi-

ration level one of the pillars of a living democracy. I want a society which is a living democracy, not only a formal one with free elections, socalled freedom of speech, a socalled free press and so on, but a democracy that is living in the sense of actually engaging as many as possible of the citizens to take an active part in the affairs of the small community where they are living, and also to take an active part in the affairs of the nation as a whole. I will give an example. Some years ago I undertook together with Mrs. Frisch, a lecture trip to Iceland visiting also some of the small communities in the north. (It is no secret that I was invited on this trip in order to help Iceland refrain from applying for membership in the EEC.) In the small communities in the north the population depends nearly exclusively on grass farming. This was in the middle of the haying season. In some place there had gathered an audience of 60 people. Think of what this means in the sparsely populated country and in the middle of the haying season. Some of them had travelled 60 km. to come to the meeting. They brought with them long papers to present and discuss after my lecture. This is living democracy.

A high aspiration level. Professor Louis W. Alvarez, Nobel prize winner in physics 1968 said: "Physics is the simplest of all the sciences . . . When we make a simple change in a system such as adding a little heat, we can easily predict that the whole thing is going to get warmer . . . But in the case of an infinitely more complicated system, such as the population of a developing country like India, no one can yet decide how best to change the existing conditions" (13). I quite agree that such problems as that of India are not yet solved. But to help solving them is precisely the high ambition of the econometric planner. The *difficulty* of such problems is our excuse for not having reached the same level of precision as the physical sciences have. *But we are on our way.* And we are hopeful that we will one day come at least very much closer to the precision of the physicists, than we are today.

It is comforting to know that already politicians in many countries do find our work useful. It warmed my heart when the chairman of the Finance Committee in the Norwegian Storting on 11 November 1969 opened that year's discussion on financial matters by a 170 words speech on behalf of a unanimous committee expressing how much the politicians owe to the efforts of the econometricians. (14).

The cooperation between the politicians and the experts

Already today there is, of course, a good deal of cooperation between politicians and experts. But on one point there is need for a new break-through, namely in making it a practice to cooperate on the formalization of the preference function. This will be of basic importance for *clarifying what the political authorities really are aiming at.*

For simplicity let me first describe how to attack the problem for a given political party.

A preparatory phase of the expert's work would simply consist in his making a systematic use of his general knowledge of the political atmosphere in the country, and in particular the political atmosphere in the party in question. The expert will have formed an opinion, *a tentative opinion,* about what the preferences of this party would look like if they were formalized in a way that fits in with the expert's model and is expressed in a language that will be understandable to his electronic computer.

In a subsequent phase the expert—on the basis of his tentative formalization—will work out a system of interview questions through which he will get *closer* to the formalization of the preferences in question. Compare the relevant parts of section 5. As a simple example of an interview question we may take the following: What would you, politician, choose if you had the choice between two packages of economic results, for instance, one package with, say 3% unemployment and an annual inflation rate of 5%, and another package with, say, 10% unemployment and an inflation rate of 1%. By repeating this question, but with different figures involved, it will be relatively easy to reach a situation where the interviewed person would say: It is all the same which one of the two packages I receive. This point of indifference is precisely what the expert is driving at. Similarly for other kinds of comparisons. There will be a whole series of such partial "package questions". From answers to a complete system of such partial questions the expert will be able to build up a preference function in its free form. If he finds it convenient, the expert may subsequently transform this preference function to a reduced form. But this is only a secondary question.

In the third phase the expert will go back to his electronic computer in which he had already entered the data regarding the core of the economy. To this he will now add the formalization of the preferences in the quantitative form as he now sees it. From this will come out a solution, in the form of an optimal development path for the economy. Optimality being defined through the preferences of this party and in the preference formalization which the expert has *now* reached.

When the expert comes back to the politicians with his solution, the politicians will perhaps say: "No, this was not really what we wanted . . . We have to change these particular aspects of your solution."

The expert will understand more or less precisely what sort of changes are needed in the formulation of *the preference function* in order to produce a solution that comes closer to what the politicians

now say they want. This leads to a discussion back and forth. In this way one will work step by step towards a preference formulation such that the politicians can say about the resulting solution: "All right, this is what we would like to see." Or perhaps the expert will have to end by saying politely: "Your Excellencies, I am sorry but you cannot have at the same time all these things on which you insist." The excellencies, being intelligent persons, will understand the philosophy of the preference questions and the expert's study of the core, and will therefore acquiesce with a solution which is not completely what they like, but at least something better than other alternative shapes of the development path which have emerged from the previous tentative solutions.

Even if we did not go any further with the formalization of the system of preferences than to work out such an analysis *separately for each political party,* an enormous gain would be obtained in elucidating the economic political discussions.

But we should not stop at this point. We should proceed to a discussion of what sort of *political compromise* that might be reached in the formulation of a unified system of preferences. And then having reached this compromise formulation, there would appear a compromise optimal solution. Here too an iteration between politicians and experts would take place.

The top political authority—in a democratic country it would be the elected Parliament—ought to concentrate *most of its time and efforts* on a discussion of this compromise on the formulation of the system of preferences, instead of using practically all of its time on discussing *one by one* the specific economic measures that might have been proposed, and for each of these measures deciding whether to accept it or not. In the way suggested the parliament would concentrate its time and energies on *the important things,* on the really vital issues. If this were done, many details could safely be left to the experts. *Big* issues would of course finally be checked through one by one Parliament decisions.

A simplified scheme for expressing political preferences regarding a *few* basic questions, is discussed in ref. (15).

7. INVESTMENT STARTING VS. INVESTMENT SINKING

I shall give an example illustrating an advanced approach to a point in the planning technique. It concerns the measurement of *investments* in an advanced planning model. If the planning model has a time horizon of more than, say, a year or two, and if investment *decisions* are an important part of the analyses, the distinction between investment *starting* and investment *sinking* (investment carry-on-activity) is essential.

7.1 *A verbal definition.* Investment *starting* in any given year is the total outlay (measured in volume figures, i.e. in monetary units of a fixed purchasing power) which it is estimated that the projects started that year will have entailed when they are finally completed—perhaps at some future date. Investment *sinking* in any given year is the measure of goods and services that were actually used (that were "sunk") that particular year in order to carry towards completion projects which were started that year or some previous year.

7.2 *The project description* is a collection of all the descriptive details regarding a project, that can be given by the specialists (technical engineers, etc.) who have detailed knowledge about this project, but do *not* have a systematic knowledge of all the broader *social, economic and political* considerations at the national level that one must take account of before one can reach a well founded decision as to whether this project is to be accepted or not.

A rational and coherent treatment of investment criteria can, I think, only be given by considering all the investment projects—defined through the project descriptions—as integrated parts of a *complete macroeconomic decision model* with all its detailed and (politically) preferential aspects. The project descriptions are building stones in the complete decision model. But nothing more.

We must stress the fundamental distinction between information that is available *before* the optimization of the decision model and information that only emerges *after* this optimization.

This distinction is the crux of the matter in planning at the national level in any country. In this optimization all the geographical, material, cultural and political peculiarities of the country come into the picture. These are parts of the core and of the preference function. This broad perspective can, of course, not be compressed into the format of a project description for a single project.

Therefore, the project descriptions belong definitely to the kind of information that is available *before* optimization. Such information is a *necessary* basis, but very far from being a sufficient basis for reaching well founded investment decisions.

7.3. *The sinking year and the starting year.* Consider a single investment project No. g

(7.3.1) t= *the interflow year* (the calendar year) is the year (or quarter or month) to which the complete macroeconomic interflow

table with all its balancing and accounting relations applies. In particular, when we are discussing the difference between investment starting and investment sinking, t will be *the sinking year.*

(7.3.2) σ = *the starting year* is the year when actual work on the execution of the project may begin. The *decision* year i.e., the year when it was decided whether to accept or reject the project No. g, is the year when the whole plan was adopted. This may be an earlier year than σ. As a rule the decision year (the planning year) will be denoted as the year 0. Research work in connection with the plan and in particular research work in connection with the project No. g may have taken place even earlier. There may be alternative σ's. The σ's take care of the *phasing problem.*

(7.3.3) $s = t - \sigma$ is the *sinking delay.* Roughly formulated the sinking delay is "the number of years that have elapsed since starting". More precisely formulated: s = 0 refers to the sinking that will take place in the *same* year as the starting (if the project *is* accepted for starting in a given year.) s = 1 refers to the sinking that will take place in the year that follows immediately after the year when the starting took place. And so on for the higher values of s.

7.4. *Sinking flows.*

In tab. (7.4.1) (g) denotes the number of different years in which sinking inputs for the project No. g will occur, roughly expressed: The *construction* period for project No. g. Also years where descriptionally $J^s = (s < (g))$ are counted.

The symbols given in table (7.4.1) are *general* symbols for the sinking flows and their totals with respect to project No. g. These magnitudes may, for instance, refer to flows that are determined already in the project description, and if so they are denoted J^{*s}_{kg} (k = h, i, B). This happens for all k and s only in the case where no *sinking substitution possibility* exists. The flows that emerge, after the decision model optimization, are denoted $\hat{J}^s_{kg}$ (k = h, i, B). These latter flows always exist and are well defined (possibly with some degrees of freedom if there remain degrees of freedom in the optimum). In a more general context the symbols J^s_{kg} (k = h, i, B) in table (7.4.1) may be used simply as indicating *variables* that enter into the decision model before optimization.

7.5 *Sinking Coefficients in the Non-Substitution Case for Sinking Inputs.* In the special case where no possibility of sinking substitution is assumed to exist, all the flows in table (7.4.1) are *fixed* and *well defined* already in the project description.

In this case we may compute the corresponding system of *sinking coefficients.* Denoting *coefficients* by an apostrophe, the sinking coefficients are:

(7.5.1) $J'^s_{kg} = \dfrac{J^s_{kg}}{H^{*tot}_g}$ [H^{*tot}_g denotes the total sinking, now assumed to be determined already in the project description. Acceptance is not yet assumed.] (k = h, i, B)

When the coefficients (7.5.1) are computed, any of the sinking flows in the project description can be expressed as

(7.5.2) $J^{*s}_{kg} = J'^s_{kg} H^{*tot}_g$ (k = h, i, B)

where the coefficients J'^s_{kg} can be read off from the project description.

7.6. *Sinking Coefficients and Equivalence Coefficients in the Case of Substitution Possibilities for Sinking Inputs.* If we have the case where sinking substitution possibilities exist, the total outlay H^{tot}_g — the sum of all items in table (7.4.1)—does not exist as a magnitude that is defined *in the project description.* The sum of all items will then have a definite meaning only *after* optimization.

In this case the *size* of the project in its full dress must—before optimization—be characterized by some other feature, for instance, by a *capacity addition* that may be associated with the project (if it is accepted in its full dress) or by some other *conventional* measure for the size of the project. Let this conventional measure of the full dress size of the project be H^{*con}_g, the asterisk indicating that this is a magnitude that can be read off from the project description, and *con* indicating that the magnitude is a conventional measure of the full dress size of the project.

Such a conventional measure may, of course, be introduced regardless of whether substitution possibilities exist or not, but in the substitution possibility case it is *necessary* to rely on such a conventional measure.

Even in the substitution possibility case there may be *some,* and perhaps *many,* but not all, of the interflows in table (7.4.1) that exist as well determined magnitudes already in the project description. And for *these particular* flows we can introduce a project description determined coefficient-concept by expressing each such flow as a fraction of H^{*con}_g, namely

Tab. (7.4.1). Sinking Flows for the Project No. g.

Sinking inputs			*Sinking delay s (after hypothetical starting year)*					
			s = 0	*s = 1*	*s = 2*	...	*s = (g) −1*	*Row Sums*
From delivering Domestic Sectors	h	1 2 . .	J^0_{hg}	J^1_{hg}	...	...	...	J_{hg}
From Domestic Primary Input Factors	i	101 102 . .	J^0_{ig}	J^1_{ig}	...	...	...	J_{ig}
From Complementary (non-competitive) Imports		B	J^0_{Bg}	J^1_{Bg}	...	...	...	J_{Bg}
Column sums:			J^0_g	J^1_g	...	...	...	H_g^{tot}

J = Gross investment (as distinct from I = net investment after depreciation).
H = "Hardware". The H's are important variables in the model. If the project descriptions are *stationary*, the J's will be independent of σ.

(7.6.1) $J'^s_{kg} = \dfrac{J^{*s}_{kg}}{H^{*con}_g}$ (For the sinking flows No. k — either h or i or B— that *are* determined already in the project description)

The dimension of (the denomination of) each such coefficient (7.6.1) will depend on the nature of the input flow in question, and on the conventional measure that is chosen for H^{*con}_g.

For the cells of table (7.4.1) for which the flow is *not* determined already in the project description, we assume that we have *instead* information about *equivalence coefficients.* For instance, if the input elements in the three cells formed by the intersection of the three rows α, β, γ, and the column s of table (7.4.1) form a sinking input *substitution ring,* the three flows $J^s_{\alpha g}$, $J^s_{\beta g}$, $J^s_{\gamma g}$ are not determined in the project description, but we have instead information about three *equivalence coefficients* $J^{*eq.s}_{\alpha.rg}$, $J^{*eq.s}_{\beta.rg}$, $J^{*eq.s}_{\gamma.rg}$ such that the three flows $J^s_{\alpha g}$, $J^s_{\beta g}$, $J^s_{\gamma g}$ must satisfy the equation

(7.6.2) $J^{*eq.s}_{\alpha.rg} J^s_{\alpha g} + J^{*eq.s}_{\beta.rg} J^s_{\beta g} + J^{*eq.s}_{\gamma.rg} J^s_{\gamma g} = H^{*con}_g$

(r = a substitution ring:
r = $(\alpha\beta\gamma)$ for sinking
input into the project g
in delay year s).

(eq = "equivalence", s = sinking delay).

Here H^{*con}_g is the conventional measure of the full dress size of the project No. g, and $J^{*eq.s}_{\alpha.rg}$, $J^{*eq.s}_{\beta.rg}$, $J^{*eq.s}_{\gamma.rg}$, are equivalence coefficients for each of the three sinking input elements α, β, γ that together form the substitution ring r = $(\alpha\beta\gamma)$ for sinking inputs into the project g in the sinking delay year s.

To take a very simplified example: Digging work connected with the project g in the sinking delay year s might be performed alternatively in any of the following three ways:

(7.6.3) α = manual labour unaided by digging machines ("chinese communes")
β = use of small and simple digging machines
γ = use of big and technically advanced digging machines

The meaning of (7.6.2) is that the amounts to be used of the three kinds (7.6.3), namely $J^s_{\alpha g}$, $J^s_{\beta g}$, and $J^s_{\gamma g}$ are *not determined by the project description* but may always be equal to the conventional full dress measure of the projects, namely H^{*con}_g. In other words, *before* optimization of the decision model we leave open the possibility that the necessary sinking input from the ring r to the project g in the sinking delay year s may be achieved either through the input element α or through β, or through γ or through any *desired combination* of these three elements, which is such as to make the linear form in the left member of (7.6.2) equal to H^{*con}_g. In subsection 7.7 we shall consider a type of *restrictions* which it may be realistic to impose in addition to the equivalence equation, but for the moment we will only discuss the equivalence equation as such.

In the sinking substitution case the individual sinking flows such as $J^s_{\alpha g}$, $J^s_{\beta g}$, $J^s_{\gamma g}$ are not determined by the project description. They are only *variables* to be introduced in the complete decision model before optimization. Therefore, in the sinking substitution

case the complete model will have *more degrees of freedom before optimization* than a similar model where no sinking substitution is permitted.

While the existence of input equivalence rings increases the number of degree of freedom in the decision model, it does not introduce any non-linearity. Indeed, the equation (7.6.2) is a *linear* equation. If the *effects* of the investment considered are to *change* the input-output coefficients, or any other coefficients in the model as it existed *before* the introduction of the substitution possibilities, then we will introduce non-linearities. This is the *infra* case.

7.7. *The complementarity restrictions that may be associated with an equivalence ring.* Consider again the example (7.6.3). In concrete reality even the most automatically advanced digging machine can, of course, not be let loose to perform the work *alone* without the aid of any manual labour. This fact may be taken account of in a number of more or less elaborate ways when we construct the complete decision model. But the *simplest* way to do it might be *still to use* the concept of equivalence equations as explained in Section 7.6, but now to complete this point of view by adding a certain type of restrictions which we may term *complementary restrictions.*

The meaning of the complementary restrictions can best be explained by changing slightly the definition of the input element α in the example (7.6.3), letting now α simply stand for "manual labour", i.e. dropping the specification "unaided by digging machines". Having changed our example in this way, we may add a restriction expressing the fact that *a part* of the variable $J^s_{\alpha g}$ has to be used as a *complement* to the variable $J^s_{\beta g}$ and *another part* of the variable $J^s_{\alpha g}$ has to be used as a complement to the variable $J^s_{\gamma g}$. If we want to *avoid* the complication which it would be to split the variable $J^s_{\alpha g}$ into *several* variables, we can express the essence of the complementarity situation considered simply by introducing a restriction of the form

(7.7.1) $J^s_{\alpha g} \geq$ some coefficient times $J^s_{\beta g}$ plus some coefficient times $J^s_{\gamma g}$.

We can formalize this idea by imposing a restriction of the form

$$(7.7.2)\quad J^{*\,com.s}_{\alpha.\rho rg}\, J^s_{\alpha g} + J^{*com.s}_{\beta.\rho rg}\, J^s_{\beta g} + J^{*\,com.s}_{\gamma.\rho rg}\, J^s_{\gamma g} \geqslant 0$$

where

$$(7.7.3)\quad J^{*com.s}_{\alpha.\rho rg},\ J^{*com.s}_{\beta.\rho rg},\ J^{*com.s}_{\gamma.\rho rg}$$

are three coefficients *that are determined in the project description.* (ρ = "restriction", or more explicitly: ρ = a restriction associated with rgs. The superscript com indicates "complementarity").

There may be *several* restrictions ($\rho = 1,2,3$ etc.) of the form (7.7.2) expressing, for instance, the fact that if we choose to use some big digging machines —input elements γ—we may need also some small and simple digging machines—input elements β—as a complement to γ.

The fact that the *coefficients* J^* in (7.7.2) are determined by the project description, does, of course, *not* mean that the actual flows $J^s_{\alpha g}$, $J^s_{\beta g}$ and $J^s_{\gamma g}$ are also determined by the project description. They are still variables. But *if* we choose to put one of these actual flows equal to a given magnitude, any complementarity restriction of the form (7.7.2) will reduce the *admissibility range* for the other actual flows.

The formal set up (7.7.2) which introduces a set of restrictions ∂ associated with rgs is a very general one. It opens the possibility of expressing *a great variety of complementary* restrictions which we may find it necessary to introduce in order to make the complete decision model *realistic* enough to cover an actual situation. *The equivalence* equations express the fact that substitution possibilities exist, while the *complementary* restrictions express the limitations that exist on these substitution possibilities.

In order not to abuse the editor's great generosity in allotting me space, I shall have to stop my little example here. Further considerations along this line are given in ref. (16). These concepts are finally worked into the complete decision model through the concepts of the *hypothetical starting variables* H. This involves many problems of a mixed theoretical and statistical sort. A survey of how the main magnitudes are book-keepingly interconnected is given in ref. (17).

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THE USE OF MODELS: EXPERIENCE AND PROSPECTS

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1. ESSENCE OF MODELS

In this lecture I propose to discuss the experience we have had with the method of model building as a contribution to economic science and the prospects for its further application. First of all I want to remind you of the *essential features of models.* In my opinion they are: (i) drawing up a list of the variables to be considered; (ii) drawing up a list of the equations or relations the variables have to obey and (iii) testing the validity of the equations, which implies the estimation of their coefficients, if any. As a consequence of especially (iii) we may have to revise (i) and (ii) so as to arrive at a satisfactory degree of realism of the theory embodied in the model. Then, the model may be used for various purposes, that is, for the solution of various problems. The advantages of models are, on one hand, that they force us to present a "complete" theory by which I mean a theory taking into account all relevant phenomena and relations and, on the other hand, the confrontation with observation, that is, reality. Of course these remarks are far from new.

While building models econometricians were often forced to *supplement "literary" theories,* since these often did not specify all relationships they were implicitly using.

Models have been built for a number of different purposes; first of all, for purposes of explaining actual developments and next, for finding ways of influencing actual development in some desired direction. Another aspect is whether short-term or long-term movements were the objective of either explanation or policies. There are large numbers of further alternatives of focussing. We will discuss some of them in this lecture.

2. SOME EXPERIENCES

First, I am going to discuss a number of experiences econometricians had with the activity of model building. Some of us were masters in hunting after high correlations, that is, *good fits* with observed values. In fact this was part of the art. Some of our critics thought this was easy enough and indicative of the futility of the activity. It wasn't always so easy, however. Some of the fits in our models never became very good, or, if finally they had been forced into a high correlation, broke down a few years later. I am afraid that the first subject I tackled in my work for the League of Nations, namely to explain the fluctuations in *investment* activity, never has become a great success. In the Netherlands Central Planning Bureau we found it safer, after some years, to ask industrialists for their investment programs rather than rely on an econometric explanation. Also government expenditures were among the variables difficult to explain. In both cases we may account for the lack of success by the fact that a small number of decision makers determine the picture and that hence random deviations will be important.

In a more general way many of us know that quite a few business cycle models were "forecasting" the turning points only *after* they had occurred. Ragnar Frisch (6) was quite right when, at an early stage of model building, he introduced *random shocks* as an essential element of the business cycle, leaving the cumulative process between turning points rather than the latter themselves as a thing that really could be explained by the models. Even so some turning points can be explained by the inner dynamics of economic systems.

In a number of cases models were hardly necessary to clarify some features of reality. I could not help thinking of this class of cases when recently I saw as a conclusion of one recent model that "Japan was a success in development". I thought we knew that already. Let me add, however, that the same model did explain something more.

During our hunting for good fits we did sometimes *learn,* as it should be. Thus, annual price fluctuations in beef prices could only be explained satisfactorily by the introduction, with a negative sign, of fodder prices some time before. High fodder prices force peasants to slaughter part of their livestock and hence depress beef prices. This was an aspect my collaborators and I had not been aware of and which

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text books on agricultural economics did not explicitly state. Another example was the explanation of the fluctuations in the general wage index in Britain before 1900 (20). No good fit could be obtained unless as one of the explanatory variables an index of mineral prices were included. After an intensive search I found that among the wages in various industries those for miners fluctuated by far the most and that for quite some time there prevailed a sliding-scale arrangement linking miners' wage rates directly with wholesale coal prices, something inconceivable to-day.

In several parts of our science, and I presume in other sciences as well, we must beware of following *vogues* too easily. Model building has become a vogue, just as, after that, linear programming or matrix algebra have become. Of course warnings against vogues are first of all coming from those who don't command the techniques implied. This is why I am myself inclined to hesitate to apply one of the two latter methods mentioned. But a critical examination of the structure of the problem before we try to solve it remains useful. And let me add immediately that linear programming does constitute a very useful technique in many cases indeed.

Returning to models, I am sometimes wondering whether, upon looking at some recent work by planners, I should not repeat the famous words by Goethe's Zauberlehrling "Die ich rief die Geister werd' ich nun nicht los" ("The ghosts I called I can't get rid of now"). Sometimes indeed some of our followers *overdo* model building.

In an attempt to evaluate what model building has contributed to the theory and practice of economic science I feel that at least we can say that models have had a *didactic* value. Often in our text books we bring simplified, not to say over-simplified, pictures of reality which nonetheless contribute to making understood some essential features of that reality. This is true already of some models inspired by Lord Keynes' fundamental work (10). It is true also of Leontief's input-output models (13). If I am allowed to quote a recent example I am guilty of myself, the same can be said of models introducing the difference between tradables and non-tradables (14). This model shows that if a country wants to eliminate a balance of payments deficit by living within its means, that is, by reducing its expenditure to its income, income itself is bound to fall and not so little.

What I called "didactic value" also stands for *communication* value. The ability of a planning expert to communicate with politicians and with citizens constitutes an important element in any type of democratic or semi-democratic planning and such communication can be enhanced by relatively simple models. In order not to misrepresent reality, however, there will be a need for a succession of models, as used in planning in *stages* or, as we now say, multi-level planning (12).

I do think, however, that the utility of models goes beyond their didactic value. They are a real and essential element in the preparation of well-coordinated policies. But they cannot do this job all by themselves. Models constitute a *framework* or a *skeleton* and the flesh and blood will have to be added by a lot of common sense and knowledge of details. Again, as framework they can be of vital importance. Some of the simplest models were sufficient to show that the investment programmes recommended by the World Bank in its early days were not of the necessary *order of magnitude*. During the Great Depression already the same could be said of some of the programmes of an anti-cyclical character.

The framework I am referring to supplies the main ingredients for coordinating government policies at the level of a central government, that is coordinating the policies of the various ministries. Already many of the details concerning one ministry only would require the introduction of partial models, or could at least be left to them.

For short-term models sufficient time has elapsed already since their construction started, in order to *test* their *forecasting performance*. Several publications of the last ten years or so dealt with that subject, comparing, among other things, forecasts made in Scandinavian countries, Britain and the Netherlands. One score of success has been the number of *turning points* correctly predicted; this score is interesting since so-called primitive forecasts, that is extrapolations of past movements, are unable to produce turning points. Some models have been able to correctly forecast two-thirds of the turning points.

A need generally felt by model builders and their critics is the need for *refinement*, that is, for the introduction of many more variables. In a way this experience again was a lesson also to economists in general, since often their arguments run in terms not showing this degree of detail. One example we in Benelux experienced: real development showed that the grossly increased volume of trade between the three countries did not imply that whole two-digit industries were wiped out in one or the other country, but only much smaller *subsectors*. Here one has to introduce hundreds if not thousands of different products in order to do justice to reality. The same applies to the problem of the *optimal division of labour* (7) among all countries of the world, although the establishment of such an optimal division of labour may wipe out more important parts of two-digit industries. Here we tried to apply the Heckscher—Ohlin principle in a very concrete way. This also implies that for the choice of the best investment projects of some developing country much preciser

information is needed than ordinary statistics can give us. It is a well-known experience that even so-called project data are far from sufficient to design the optimal development policy.

Two other examples of the need for refinement of models may illustrate the case. One has been often mentioned by Erik Lundberg (15) in his analyses of *anti-cyclical policies,* mainly financial policies. Partly we have a need here for much smaller time units and corresponding information, for these time units, on a number of relevant variables. Among the variables are a number of expectations not usually collected by statistical bureaus or even central bank statistical departments.

The other additional example of the need for more refined models and information can be taken from the experiences of the United Nations Research Institute for Social Development (UNRISD). The essential feature of this Institute's work is to include a number of so-called *social* variables. Leaving apart the question of how to define these variables—at present we have three different definitions competing—in two ways refinement is needed. On one hand, information about many more aspects of social phenomena is needed. Taking education as an example, the usual data available, such as enrollment, are too crude and should be specified, say, with regard to the type of education. On the other hand, data for smaller geographical units are needed, closer to what in other contexts is known as the "grass roots". The intuitive judgment of several sociologists that research and inquiries at this lowest level are by far more productive than the macrosocial research undertaken by UNRISD should be so interpreted (17). This implies that the question is not whether quantitative models are or are not productive. Precise knowledge about interrelationships can be obtained only by the technique of quantitative models; but the lack of homogeneity of crude information is the reason for the lack of success in the social area and hence refinement of the base material is the real need here.

All these refinements will make for ever more complicated models and therefore threaten to make models unmanageable. This once again underlines the need for several stages of decision-making and hence of planning. As already said, the need for communication with the people and groups involved also points in the direction of this step-wise use of models. So also does the *organizational* aspect of decision making; a correspondence between the organizational setup of an optimum socio-economic order and the levels or stages of planning and the use of models for it is desirable. One of the future features of such a setup will also be the more precise location of the flows of *information* and, more particularly, the type of information needed.

3. PROSPECTS OF MODEL BUILDING

Let us now turn to the future of model building. The primitive state of the art has become clear from our preceding remarks. We have already indicated some of the directions in which models will have to be developed. Our present subject, the prospects of model building, of course overlaps with the subject discussed so far. As a consequence, some repetition cannot be avoided; but we will approach the subject from a somewhat different angle. Our central question will now be what extension should be given to the scope of model building. Some of the developments to be discussed have already been started.

A first subject to be dealt with refers to the necessity to introduce the element of *space* into socio-economic models. For a long time this aspect of economic science has been neglected. Relatively few authors have dealt with it. As a consequence there is a clear gap between economic models on one hand and the practice of town and country planning or transportation planning on the other hand. Town and country planning is carried out more often by engineers, architects, geographers, and sociologists than by economists. Economic science may and has to contribute, here too, to some more co-ordination between the contributions made by the other sciences or arts just mentioned. In his dissertation Bos (3) has offered some interesting new approaches to the problem of the optimal spatial dispersion of economic activity, using some results of Serck Hanssen's. The main new entities entering the picture after the work done by Losch are *"centres"* which is a concept covering villages, towns and cities of all sizes. Centres are clusters of production units and the complementary dwelling units. The main problem is how to group the production units into centres of different size and composition so as to maximize welfare of, say, a country, under a number of constraints. Some of these constraints are production functions in the usual sense, others are the specification of transportation costs arising from differences in location. In a recent publication Mennes and Waardenburg (16) have elaborated on the subject especially for larger spaces, usually called regions, countries and continents. In some cases they arrive at satisfactory approximations by what might be called *"two-stage Hitchcock solutions",* that is by the consecutive application of two Hitchcock or transportation problem solutions, a simpler brand of linear programming.

Together with Herman (8) the same authors have elaborated elsewhere an example of what could be called a *multi-level semi-input-output model* (4). By this model they are able to take into account the existence of more than one level of "tradability".

Some products may be tradable between regions of one country but not between countries. Other goods may be tradable between the countries of one continent, but not between continents. As a consequence the expansion, in a given region, of an international industry may entail necessary investments bound to the region, others bound to the country and still others bound to the continent. The impact of such an expansion on the economies of the country and the continent concerned are similar to, but more complicated than, the impacts studied by the semi-input-output method with one level of non-tradability.

While these various examples show the picture of lively activity in the field of the economics of space, it is clear that some fundamental features characteristic of the subject can hardly be included already into the methods used. On one hand, empirical data are lacking on such features as *external effects* and on the other hand mathematical techniques are lacking—or at least not known to my collaborators, let alone to myself—needed to generalize sufficiently the models developed as examples.

A second subject to deal with, in discussing the widening of the scope of economic models, is the inclusion of so-called *social* and *political* variables. As already stated I do not intend to discuss to-day which of the three alternative definitions of social variables should be preferred. In all three most of *education* will be considered a social activity. Some models of education have been developed of late (19). Because of the long lags involved, the education process is one of the best examples of the use of difference equations, even if Balogh's warning (2) is taken into account that quality aspects are particularly important in this field and sometimes are the aspects in immediate need of change. With the increased awareness of the role of education in economic and social development and with the budget for education being among the largest budgets of the various ministries, the need for further work in this type of model can easily be understood.

Another social subject is *income distribution.* Models for its explanation as well as for its manipulation have been developed, some of them long ago already. As in other cases the need for a large number of variables is quite clear also here. Correspondingly, there is a need for a large volume of information especially with regard to the description of jobs offered by the production process and of skills available with the population. For the last thirty years a tremendous material on job evaluation has become possible, mostly for manual workers and adminstrative personnel, using an about twenty-dimensional vector to describe jobs. It should be possible —although some psychologists deny this—to arrive at a corresponding vector describing the available skills. Elsewhere (21) I described a model which may serve as a framework to find the resulting distribution of labour income. To be sure I used two dimensions only in the concrete elaboration; but there are indications that the twenty dimensions used in practice are intercorrelated to a considerable extent. Some earlier authors have worked with one dimension only; sometimes the IQ is used and another proposal has been (22) to take the degree of leadership as the one variable describing a man's ability to produce. These must be oversimplifications, of course, but with far less than twenty criteria one could probably attain a satisfactory first approximation. As a quasi-capability component a person's wealth may be introduced. Models of this kind may soon be used to study in a more precise way also the possibilities to change income distribution and, for example, to find out what degree of inequality is inevitable. In the light of the renewed interest for these questions—I think of Jamlikhetsrapporten of SAP and LO—models of this kind may well be elaborated further. The main policy instruments to be used in order to reduce inequalities, tax and education policies, can be built in into the model without difficulty.

A third example of the simultaneous introduction of many social and political variables into models, especially for developing countries, is the impressive attempt made by Irma Adelman and her collaborators (11) using factor analysis and discriminant functions in order to discover, which of some thirty odd factors, measured in a heroic way, seem to play a preponderant part in the process of development. One may wonder, with Tjalling Koopmans, whether such "measurement without theory" is meaningful; as an exploration of a new territory of science I think it is. But prolonged discussions of the type already started during the Christmas meetings of the American Economic Association 1968 will be needed to disentangle the complicated and daring combination of theory and testing produced by three women, for which they deserve our admiration (5).

The third subject to be discussed under the heading of widening the scope of models is the one of *specifying optimum socio-economic orders.* Optimization is not a new subject, of course. Mathematical programming models are now widely used, both on the level of the production unit and on higher levels. Scientific development took place along the various tracks. Among the most sophisticated we have had, in recent years, dynamic models for long, even infinite time periods, such as developed by Phelps (18), Tj. Koopmans (11) and M. Inagaki (9). Among the results attained by these authors are the limits set to our freedom to choose some parameters which we might have thought we are free to choose, such as the time discount occurring in a preference function. For some value intervals of this parameter Koopmans has shown that no preferential ordering of the vari-

ous conceivable development paths is possible. Results of such as these belong to the really fundamental features of economic science. Inagaki has introduced the other fundamental idea that some older models only apply to a "society of immortals", though not meant for the French Academy. He then introduced the concepts of the *generation at time t*, representing an "ensemble renouvele" or a self-innovating set, and *"instantaneous government"*. I cannot discuss this subject any further, since I did not study it in sufficient detail, for lack of mathematical knowledge.

There are two other tracks, however, which I want to sketch out. One is the discussion of the social welfare function, or the objective function. I share the opinion of those, like Frisch and Bergson, who think that the scientific strategy of official welfare economics has not been optimal. By this I mean that, in our opinion, it is better first to specify the social welfare function as precisely as possible and then to use it for finding the socio-economic optimum. In a discussion with Kornai about his outstanding book I proposed that both East and West try to specify their social welfare function so as to see whether the ultimate aims are very different or not. Hopefully some thorough work will be done on this subject in the coming years.

The second other track I want to sketch out is to *reformulate* the problem of the socio-economic optimum. The true unknowns of the problem are not so much the quantities of consumption and productive effort to be made and a few more traditional unknowns, but rather the *set of institutions* which taken as a set are able to approach the welfare economic optimum as well as possible. So far the method followed by some of us, interested in this version, has been to formulate the conditions the optimum has to fulfil and then to indicate a set of institutions which, by their behaviour equations, would produce the same conditions. Thus, in olden days, when too simple production functions were assumed to represent the available production processes, men like Adam Smith or Vilfredo Pareto suggested that private enterprises and competitive markets would do the job. Today we look at these things somewhat differently and arrive at other suggestions. One particular subproblem worth being mentioned is the problem arising from the existence of *costs of institutions*. Some types of taxes, for instance, show quite considerable costs to collect them. How do we have to deal with these costs if the institutions to be chosen are unknown beforehand? The phenomenon of costs of institutions requires a reformulation of the optimum problem so as to take into account these costs if and only if the institution causing them is chosen as an element of the set of institutions constituting a solution to the optimum problem. Some first attempts by my collaborator Waardenburg make us hope that a way out will be found.

It is also our hope that the interpretation of the socio-economic optimum as a set of institutions may help to get under way a discussion of a more scientific character than was usual so far about the relative merits of various existing socio-economic orders, especially those of Eastern and Western Europe, including such interesting cases as Sweden, Switzerland and Yugoslavia. A considerable amount of better information about various types of external effects will be one of the necessary ingredients if we want to give concrete content to such merit rating of various systems. It is my hope that in such a way we may again, as Marx claimed, find scientific arguments in the competition between various systems, but up-to-date scientific arguments rather than obsolete ones. This more fundamental research in economics deserves relatively more attention and resources than the more superficial versions of economic research directed at forecasting or analysing very short-term fluctuations in market prices, on which quite some money is being spent to-day.

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THE MAINSPRING OF ECONOMIC GROWTH

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In my *Theory of Wages,* first published in 1932, there is a chapter (VI) entitled "Distribution and Economic Progress". It was the first to be written of the theoretical chapters in that book; so it is in a sense the first of my contributions to economic theory. I do not think much of it now; I think that I have learned a good deal since I wrote it. It has nevertheless had a considerable progeny. Work that is based upon it, or on other constructions of the same character, continues to appear; so it is far from being dead. Yet I myself have moved away. It may be useful to take this opportunity of explaining how this happened. It is not inappropriate to do so, since in doing so I shall describe what seems to me to be an important part of the work I have done, in all the time from 1932 to the present.[1]

It was characteristic of that approach, from which I began, that it treated the Social Product as being made by two Factors of Production, Labour and Capital: the services of Labour and the services of Capital contributing to the Product in much the same way. An increase in the amount of either Factor that was applied would increase the Product, *other things being equal.* With given amounts of Factors applied, there would be just so much Product; so (again other things being equal) there would be a Production Function (as it later came to be called) representing Quantity of Product as a Function of Quantities of Factors applied. The return, per unit, to each Factor was equal to its Marginal Product, which diminished as the amount applied of that Factor increased, the amount of the other remaining constant. It followed at once that an increase in the quantity applied of one Factor (that of the other remaining unchanged) would increase the absolute share of the Product going to the other Factor: but since the absolute share of the increasing Factor might be either increased or diminished (according as its Marginal Productivity curve was elastic or inelastic) the distribution of the Product between the Factors (relative shares) might be shifted either way. Which way it went would depend upon the "shape" of the Production Function, a "shape" which could be represented, as I showed, by what I called the "elasticity of substitution".

It was not supposed that the Production Function would remain unchanged over time; it would be shifted by the discovery of new techniques of producing—that is to say, by *invention.* Inventions, so Wicksell appeared to have shown (and I followed him), would not be adopted unless they raised the Social Product; but the shifts in the Production Function, due to invention, might be "neutral", as far as distribution between the Factors was concerned, or might be biased either way. It seemed to me that rises in wages (rises, that is, in the share of the Product going to Labour per unit of Labour) would encourage the adoption of inventions which economised in Labour and so were biased against Labour; but whether such "induced inventions" were to be regarded as shifts in the Production Function, or as substitutions within an unchanged Production Function, was left rather obscure.

The theory, which I have been outlining, has been decidedly influential; but almost every element in it has been a target for criticism. Some of the criticism (such as those directed against the Marginal Productivity theory as such) can, I still believe, be rebutted, or partially rebutted but there is one that remains which I now feel to be decisive.

In the Production Function, "Product", "Labour" and "Capital" are quantities; but it is necessary, if they are to be quantified, that there should be some means of reducing their obvious heterogeneity to some kind of uniformity. For none of the three is the reduction a simple matter; it cannot be solved, even in the case of Labour, by counting heads or by counting man-hours. The crucial problem, however, is that of capital.[3] Capital, here, must mean physical capital

*All Souls College, Oxford. Lecture J. R. Hicks delivered in Stockholm, Sweden, April 1973, when he received the Nobel Prize in Economic Science. The article is copyright © the Nobel Foundation. It is published here with permission of the Nobel Foundation.

[1]As seems suitable in this place, I shall confine this account to the evolution of my own ideas, without much attention to what I have learned from others. How much I have learned from others especially, perhaps, from Roy Harrod, Joan Robinson and Nicholas Kaldor will nevertheless, I hope, be apparent.

[2]As I have explained in the *Commentary* attached to the second (1962) edition of *Theory of Wages,* especially pp. 333–41.

[3]Crucial in the sense that it has been the major theme of controversy among economists. I accept that the aggregation problems, on the side of Product, are hardly less pressing.

goods; it is an aggregate of physical goods which we have to represent by a single quantity. As is now well known (but was not so well known in 1932) there are just two cases in which this can be done without error—without any error, that is, for it is not denied that if either case is approached, without being actually reached, the error may be tolerable. One is the obvious case in which all components change proportionately; the other—which I myself may claim to have clarified in 1939—is that in which the price-ratios between the goods, or their marginal rates of substitution, remain constant.[4] In the former case the complex is representable by a number of physical "bundles"; in the latter there is aggregation in value terms.

It is clearly impossible, in the case of the capital stock, to claim that the first of these conditions, in practical application, can be even approximately satisfied. For it is normal experience, in a progressive economy, that its capital, at the end of a period, contains different kinds of goods from those contained at the beginning. New items are introduced, and old items discarded. Only in a theoretical construct—a steady state—can proportions remain unchanged over time; and we can hardly make much use of that property, even for the comparison of steady states, since proportions in one steady state will usually be different from those in another. There is little hope for a way out in that direction.

The other, at first sight, looks more appealing. Here however there is a more subtle objection, associated in particular with the work of Joan Robinson.[5]

If capital increases relatively to labour, other things being equal (so the Production Function theory appears to tell us) the marginal product of capital must fall, so the rate of return on capital must fall. But a fall in the rate of return on capital carries with it a fall in the rate of (real) interest, as a result of which the capitalised values of different goods (goods of different durability, for instance) must change disproportionately. So the marginal rates of substitution between them cannot be kept constant. The constant-price condition cannot be maintained; it involves a contradiction.

This does not mean that it is wrong for statisticians to value capital goods at constant prices—their prices, or costs of production, at some base date. Any practical measure of National, or Social Capital must I think be of this character. But a technological relation between Capital and Product, with Capital thus arbitrarily valued, carries no conviction; there is no reason why it should exist.[6]

All I have said so far is by way of preface. I have, on the whole, left it to others (since my early days) to live in the world of production functions and elasticities of substitution, between Factors globally defined. What I mainly want to talk about is a side of my work which has gradually developed over the years, and which, I now feel, is more promising.

It also goes back to that same *Theory of Wages*. I have so far been discussing Chapter VI; but there are other chapters (IX–X) where will be found the beginnings of quite a different theory. These are curious chapters; their reception, when the book appeared, was much less favourable than that then accorded to Chapter VI. This was partly because the tradition in which I was working in IX–X—the tradition of Bohm-Bawerk and Wicksell—was much less familiar to English readers than that of Pigou, on whom I was drawing in VI; but mostly because of a head-on collision between what I was saying and the "New Economics" which even then, three years before the *General Theory*, was already beginning to be the Economics of Keynes.

When I wrote the *Theory of Wages*, I was completely innocent of these ideas; I had scarcely a notion of what was going on at Cambridge, or for that matter in Sweden. But hardly had my book left my hands when I began to move in that direction myself. I stumbled upon something which, if not quite the same as Keynes's Liquidity Preference, has a close relation to it. And even before the *General Theory* appeared in 1936, I had begun to draw some of the consequences.[7]

There is much of my work which follows from that; I have no time to describe it here. I must keep firmly to the story of those chapters in the *Wages* book, and what follows from them. The first result of the new point of view, when I reached it in 1933–35, was to make me deeply ashamed of what in those chapters I had written. I realised (too late) how inappropriate it was. It had nothing to do with the state of the world at the time when I was writing. I had diagnosed a disease, but it was not the right disease. The unemployment of 1932 was of quite a different character from what I had supposed.

It is nevertheless not useless to analyse a disease, even if it is not the disease which at the moment is important. The time may come when one's work is more to the point. In my case, I think, it has come.

The principal ground on which my chapters were attacked, in the thirties, concerned my initial assumption—that Trade Unions, or Government wage-fixers, can raise *real* wages. This, by Keynes and his followers, was in those days most resolutely denied. Trade

[4] *Value and Capital* (1939), p. 33 and passim.

[5] *The Production Function and the Theory of Capital* (Review of Economic Studies 1954); and later writings.

[6] I have stated my present views on the Production Function at greater lengths in *Capital and Growth* (1965) pp. 293–305; and in *Capital and Time* (1973) pp. 177–84.

[7] *A Suggestion for Simplifying the Theory of Money* (*Economica* 1935, reprinted in my *Critical Essays in Monetary Theory, 1967*). I have told the story of my "conversion" in *Recollections and Documents* (Economica, February 1973).

Unions, they said, are concerned with money wages, not real wages. It is true that a rise in the money wages of a particular group will raise their real wages relatively to those of others; but a general rise in money wages, in a closed system, will simply result in a rise in prices in the same proportion, thus leaving real wages where they were. This of course implies that there is an elastic money supply. If the money supply is not increased proportionately, the rate of interest will rise; as a result of the rise in interest there will be a fall in the demand for labour. The cause of the unemployment is then identified as the inelasticity of the money supply.

It is fairly obvious, in these days, that this Keynesian argument is not so strong as it at first appeared. Directed, as it was of course at first intended to be directed, against the use of wage-cuts as a means of stimulating employment in depression, it retains its force. But it is much less strong on the other tack.

Though Trade Unions operate on money wages, it is surely in real wages that they are really interested. If a rise in money wages just leads to a rise in prices, they feel themselves cheated: so they return to demand another round of rises in money wages. Thus we get the cost-inflation, with which (during the last twenty and especially ten years) we have become so familiar. It could not occur without an elastic money supply; so why not put constraints on the money supply, and so check, or at least impede, the inflation? There are bound to be monetarists who will argue that way, and governments, in desperation, are bound to give some attention to them. Is the resulting unemployment then due to the monetary constraint, or to the wage–push which led to the monetary constraint being imposed? One can look at the matter either way, but it can well be argued that the latter way is the more fundamental.

So my 1932 analysis has come, at last, to some sort of contemporary relevance: but there is another kind of relevance, of which I had no suspicion when I wrote, but which has been there all the time. This is not a matter of analysing a disease; it is concerned with the normal growth, the healthy growth, of an economy. In healthy growth real wages should be rising. What are the consequences of that rise in real wages? My 1932 analysis was concerned with rises in wages off the normal path: but the rises that are on the normal path should have similar effects, though they will not include the causation of unemployment. Rather similar methods should be usable for their analysis: it should deepen our understanding of the growth process in general. This is the aspect in which I have lately been mainly interested. I will try to sketch some of the results I seem to have been reaching. This will be the subject of the rest of this lecture.

I have talked all this time about those chapters IX–X of the *Wages* book, without specifying what they contain. Much of what they contain is detail, now irrelevant. There is just one thing that matters.

A rise in *real* wages, however caused, tends in itself to diminish the *real* rate of profit. This has two effects which work, in a sense, in opposite directions. One is to encourage the substitution of what are usually more capital-intensive methods; the other, because of the transfer of income from profits to wages, is to diminish saving. Far more is now known about both of these effects than I knew in 1932; but the distinction still holds. I will try to re-state it in a more modern form.

The first thing on which to insist is that it is quite unnecessary, because we use terms like "capital-intensive" and "rate of profit", to trouble ourselves about the valuation of the capital stock as a whole (as we appeared to have to do on the *production function* method). What matters is not the average rate of profit on the whole capital stock (which cannot be determined without such valuation); what matters is the rate of profit on *new investment*. When the new investment is undertaken, that profit is no more than an expected profit, and what is realised may not be the same as what is expected. It seems reasonable, however, if we are concerned with healthy growth, to suppose that there is some broad concordance between what is expected and what is realised. Most ventures come out more or less right. No more than that is required.

It cannot be profitable (in this sense) to make machines unless the use of the machines is also profitable; so, to assess the profitability of investment, we should look right forward to the production of final product. In any production plan, so considered, labour is input and final product is output; so a rise in wages, in terms of final product, must diminish the rate of profit on the plan, in terms of final product. To this rule there is I believe no exception. It holds for any plan that could be viable at the rate of wages in question.[8] So for any plan (with inputs and outputs expressed in quantity terms) there is a particular relation between (real) wage-rate and (real) profit-rate, which can be drawn out as a downward-sloping curve—what I now like to call the "efficiency curve" of the plan.

Next (though only provisionally) let us make the conventional assumption that "technology" is given; that there are just so many production plans, in the above sense, from which choice can be made. Each such plan will have an efficiency curve. Make the "capitalist" assumption (I am not here concerned with the question of its justification) that the plan which is actually chosen for new investment is that which gives the highest return at the current rate of wages. It could be that the choice was unaffected by the level of wages; but it makes more sense to sup-

[8] *Capital and Time* (1973) ch. 2.

pose that as wages change, different plans (or techniques) will come to be the most profitable. There will then be substitution along a "spectrum of techniques" as wages rise.

It is not the case (as used to be supposed) that there is any single physical index by which we can distinguish those techniques which lie "further down" the spectrum from those which lie "higher up". There is no such index which can be employed without exception. I could already show (in 1939) that the "Period of Production" that was used for this purpose by Bohm-Bawerk and Hayek will not in general serve.[9] But what is in substance the same argument can be used against any physical index, such as capital-labour ratio (when capital, by some device, is physically defined).[10] We should not allow these refinements to obscure the fact that techniques which lie further down the spectrum (so that they require for their profitable adoption a low rate of profit, or interest) will *usually* be such as to involve higher preparatory costs, such as construction costs, as a means of economising in running costs of production. We do not *usually* go astray if we think of such techniques as being in that simple sense more capital-intensive.

I shall later return to this substitution effect: for the moment I turn to the other, which is more troublesome. In *Theory of Wages* (as was natural at the date when it was written) I took the traditional view that more saving meant more capital accumulation, and that capital accumulation was favourable to rising wages. But in Keynes's system of thought, which was so soon to be sprung upon me, the effect of saving seemed to go the other way round.

The trouble was not (as might easily be supposed) that Keynes's theory was monetary, while my "classical" theory was non-monetary. One can construct a "barter" system, in which money plays no essential part, but which can still behave in the manner that Keynes identified. (It is not, incidentally, such an unrealistic construction; the world, in 1970–1, produced quite a good imitation of a Keynesian slump *in real terms.)* It has taken some time for this to be clarified—since Keynes himself, by unfortunate definitions which made saving and investment always equal, obscured the significance of a part of what he was saying.

If we make the distinction (which already in 1936 was familiar in Sweden) between desired and realised saving and investment, the issue becomes much clearer. In the desired sense there can be an excess of saving over investment, even in a barter economy; it will take the form of an undesired accumulation, an accumulation of surplus stocks. If there is an excess of investment over saving, in the desired sense, stocks will fall below normal, below what is desired; or surplus orders will pile up, orders which cannot be satisfied without abnormal delay. Such an excess, either way, may be regarded as a sign of disequilibrium—a disequilibrium which is perfectly possible, even in a barter economy.[11]

Saving-investment equilibrium, so defined, does not imply the Full Employment of Labour; for that also to be attained, further conditions are necessary. One of the conditions is that relative prices should be right. It is unnecessary, here, to discuss the vexed question whether it will always be possible, in a barter system with sufficiently flexible prices, to maintain both full employment and saving-investment equilibrium automatically. (I am myself convinced that it is not necessarily possible, but that is by the way.) What is important, for my present purpose, is that saving-investment equilibrium and full employment are different. One can suppose that there is saving-investment equilibrium, maintained continuously; and yet there can be unemployment, if the ratio of prices to wages is inappropriate. That is what I ought to have said in *Theory of Wages.* So interpreted, the Keynesian view and the "classical" view fit together.

It has taken a long time to clear this up. In the central part of my *Contribution to the Theory of the Trade Cycle* (1950) I used what I have later called a *fixprice* model.[12] I introduced an equilibrium path—a saving-investment equilibrium path—and a full employment path which lay above it. I was interested only in departures from equilibrium; so the only function attributed to the full employment path was to act as a Ceiling, which imposed a constraint upon the disequlibria which could occur. I did not ask why the equilibrium path should lie below the Ceiling. Indeed, I said much too little about each. I just drew them as straight lines—which is a simple way of saying nothing about them!

The natural way of finding out more about them is to consider the possibility of maintaining *both* saving-investment equilibrium *and* full employment. Suppose that both conditions have to be fulfilled; what will be the consequences? Real wages, it is clear by now, will have to be flexible; can they be kept flexible always upwards? If they can, it may be that the simultaneous satisfaction of both conditions can be maintained without friction (this does not mean that it must be attained); if they cannot, if there must be fluctuations in real wages when both conditions

[9] *Value and Capital* ch. 17.

[10] This is the principal point which the "re-switching" controversy is about. For further detail, see *Capital and Time,* ch. 4.

[11] The disequilibrium which in a closed economy is revealed by physical stocks is in an open economy mainly revealed by foreign exchange—the balance of payments. For foreign exchange, in a modern national economy, is the easiest stock to run down, or pile up.

[12] See especially Chapter 8 of the book. Also *Capital and Growth* (1965) chapters 7–11.

are satisfied, there will surely be greater difficulties. To learn more about the *double-equilibrium path* (as we may call it) seems thus to be the next thing required.

It has been widely appreciated that it is the next thing required. Many (though by no means all) of the "growth models" that have been developed on all hands during the last twenty years can be considered as answers, or attempted answers, to the question just put. Some of them, especially those labelled "neo-classical", use the production function scheme I began by describing. I am myself untempted by that procedure, essentially for the reason given. It may nevertheless be agreed that the problem is a "classical" problem; since we are putting disequilibrium behind us, what we have learned from Keynes is for the moment irrelevant. It is to the classics that we must go for help. We shall find it, in my view, not in the "neo-classics" but in the British Classical Economists, especially in John Stuart Mill.

When Mill "abandoned the Wage Fund" he must have forgotten what he had said about it. (It is not surprising, in view of all the other things he had been doing, if by 1868 his recollection of his earlier work had become a little rusty.) In terms of the double equilibrium path, what is said in his *Principles* is substantially right. The wage-bill (the *real* wage-bill) is just the difference between final product and what is *taken out* of that product for other purposes. What is taken out will include not only "consumption out of profits" but also the consumption of public bodies (as Adam Smith, when he was on this track, had been well aware). So long as the increment in this Take-out does not exceed the increment in final product, the real wage-bill must increase when final production increases. It must do so, along the double equilibrium path.[13]

We can at last begin to see how the substitution effect and the saving effect fit together. It is essential to hold fast to the behaviour of *final output.* This is the chain of causation: from investment to final output, from final output to wages, from wages to the rate of profit on new investment, and thence back on investment itself. There is much to be said on each of these steps. I cannot go into detail, but must confine myself to giving a general impression.[14]

Let us start from the making of an invention, which we had better think of as a major invention, so that the technique of production which it makes possible is much more profitable than any used before.[15] It needs to be embodied in new equipment in order that it should be used; so without new investment it cannot be applied. But even if the invention had not been made there would have been some new investment; so the immediate result of the invention is that the technique which is embodied in new investment is changed. The rest of the economy proceeds more or less as before, using old techniques; they are now obsolescent, but they cannot be changed overnight.

The *new* processes will not produce final product at once; there must be a delay before the new equipment comes into production. During that delay, all final product comes from old processes; so (in double equilibrium) the old processes must continue in full production if final product is not to fall. Except by a fall in final product, no additional resources can be transferred to new investment; so it is just the resources which would have been employed in new investment, if the invention had not occurred, which can be transferred to the making of the new "machines".

It is by no means certain that final product will be increased even when the equipment comes into production. For it may well be that the increased profitability of the new machines is simply a matter of reduction in running cost. They have no larger capacity than the machines they replace; it simply costs less to run them. There is then no rise in final output when the new machines come into production. What does happen is that resources are released; but if double equilibrium is to be maintained, they must still be employed. They may be employed in squeezing additional output out of old processes; or they may be employed in making new machines. In the former case, there will at that stage be a rise in final output; and even in the latter case, though there is again no increase in output while the extra machines are being made, there will *in the end* be an increase in final output. So it *is* true (as Wicksell supposed) that a profitable invention will always lead to an increase in final output; but it is perfectly possible that the increase may be long deferred.

Unless the rise in final output is absorbed by an increase in Take-out, or has to be spread over too large an increase in the supply of labour, rising final output (when it comes) will mean a rising rate of real wages. (This is where substitution will come in.) But suppose for the moment that there is no substitution and no further *invention.* Investment continues on the same pattern as was established after the first invention occurred. Gradually, as old machines are replaced, the part of the capital stock which has become obsolescent will diminish; more and more will be of a "modern" type. During all that time final product will be expanding, and wages rising. As wages rise, the rate of profit will decline, from the exceptional level reached just after the original invention, towards something more "normal". It will decline, though not before the modernisation has been completed, to the level which is appropriate to

[13]On Mill, see *Capital and Time,* pp. 58–62.

[14]There is a much fuller discussion in *Capital and Time,* chs 9–10.

[15]In the case of an open economy, the opening of a new market for an export, or potential export, will have a similar effect.

a steady state under the new technique; for the level of wages which is established in that steady state is the highest that can be achieved (except by diminishing Take-out) so long as there is no substitution and no new invention.

We need not rely, to establish this conclusion, on the "classical" view that a declining rate of profit will diminish the *incentive* to save.[16] Whatever be the nature of saving propensities, an approximation to a steady state is likely to occur, *if there is no further technical change.* It will be a different steady state, with a different distribution of income, according as saving propensities take one form or another. But it will always be a steady state; and in that state wages will always be higher and profit lower than they were on the way to it.

Now we can bring in substitution. If there is substitution along a spectrum of techniques—new techniques which would previously not have been profitable becoming profitable because of the rise in wages the fall in profits will be slowed up. The effect of the substitution (in most cases at least) will be in the direction of adopting more capital-intensive techniques. These will probably, at their adoption, slow up the rise in final product; and that probably means that they will slow up the rise in the rate of real wages. (Since they are directed towards economising in labour, it is not surprising that they should slow up the rise in wages.) But—and this is vital—the result of the substitution will be to set the economy "aiming" at a steady state with a higher final product per unit of labour, and therefore (with any reasonable behaviour of take-out) a higher level of wages. There are several ways of establishing this essential proposition;[17] the simplest, perhaps, is just to observe that in the steady state, when the system is fully adjusted to the new technique, every worker will have more "capital" to help him when the method of production is more capital-intensive.

What I have just been giving is no more than an exercise; it does no more than distinguish one causal sequence which in actual experience will be crossed and mixed up with many others. It does nevertheless appear that this sequence may be rather fundamental. The mainspring of economic progress, it suggests, is invention; invention that works through the rate of profit. Each invention gives an *Impulse,* as we may call it; but the Impulse of any single invention is not inexhaustible. The exhaustion is marked by falling profit; but the cause of the exhaustion (on the Full Employment, or double equilibrium path) is scarcity of labour.

In saying this we are keeping, in substance, quite close to Mill. In Mill the "declining rate of profit" is due to scarcity of land; but there is no reason in principle why the operative scarcity should not be any natural scarcity. Mill's view that the operative scarcity was land scarcity can only be regarded as empirical; it looked like being right at the time when he was writing, but over the whole time since then it does not look like being right. The ultimate scarcity must be that of labour *or* of land (or both); formally, it must be scarcity of some non-augmentable factor of production. There are of course many other scarcities which will arise in the working-out of the Impulse; but scarcities that can be overcome by investment will not reduce the rate of profit on new investment in general. They will shift the point on the productive process where the investment is to be made, but that is all. It is only the irremovable scarcities which will ultimately compress the rate of profit.

Once we recognise that substitution, on the spectrum of techniques, is just one way of overcoming the scarcities that arise out of the Impulse, many things fit into place. If there is no technical change, following on the original invention, other than that which is directly implied by the invention, the Impulse which it gives will soon be exhausted. Scarce factors will then get the full gain which accrues to them from the original invention, but no more. But if there is substitution, directed towards economising in those same scarce factors, the ultimate gain to them will be greater, and may well be far greater. There may still be a question of how the gain is distributed between them. Taken together, however, they must gain in the end from the deferment of exhaustion.

It is of little importance, from this point of view, whether the substitutions are supposed to take place along an unchanged "technology frontier", or whether they themselves partake of the nature of invention. The "technology frontier", useful as it has been in the formation of the theory, and still (perhaps) indispensable in the first stages of presentation, is in the end a piece of scaffolding, that we can take down. The puzzles about "induced invention" then give no trouble. We have just to define them as technical changes, the possibility of which is newly discovered in the working-out of the Impulse, and which are such that it would not be profitable to make them until the scarcities by which they are "induced" have developed. They thus appear as secondary inventions, "children" of the original invention, its "economic children"; for we may surely allow it to have other "children"—technical children, "learning by doing" in a most extended sense—as well. The economies of scale, on which one school of economists lays such great stress, may well be introduced in much the same place. The great inventions will give great and long-lasting Impulses, because they have many "children", of all these kinds.

It will clearly be difficult, in relation to contemporary experience, to draw a firm line between the pri-

[16]Nor even upon the sophisticated re-statement of the "classical" view that is due to Cassel *(Nature and Necessity of Interest).*

[17]My own preferred way is that which is set out in *Capital and Time* ch. 10.

mary invention and its "children", when the latter are so broadly defined. Where the distinction is drawn is bound to be a matter of judgement, or of taste. In relation to earlier ages, where claimants to primary status are less thick upon the ground, the distinction may be easier.[18] One can certainly detect, in the nineteenth century, one major invention that gives a recognisable, and separable, Impulse—the railway. The Railway Age was an Impulse, the working-out of which is clearly visible, since there seem to have been at least a couple of decades in which no Impulse of comparable magnitude followed. Many economists (including sometimes Keynes) thought the Depression of the nineteen-thirties to be a Pause of similar character. That could be, but it does not have to be, since the Disequilibrium of the thirties can well be explained in other ways. It is impossible to tell its story without laying great stress upon the monetary aspect, which I have been disregarding; it may well be that it is right to tell the *whole* of its story in those terms. Yet there may be something more. It would be a great help if we knew, better than we do, if there was something more; for it would help us to understand the innovative process, as it works in this century, and so to know, better than we do, how far we can count upon steadiness in the flow of innovation. The study of past Impulses, with the aid of a better classification, might well throw much light upon this vitally important matter.

I return, in conclusion, to the *Theory of Wages* problem—the consequence of maintaining a level of real wages which is higher than that which is appropriate for double equilibrium. After what has been said, we need not conceive of this problem in a static manner. The equilibrium wage-level may be allowed to be rising, but the actual wage-level is kept, all the time, somewhat above it. That this is a realistic problem cannot nowadays be denied; for the means that are available for the enforcement of such a wage-level are far more extensive than they were in the past. Granted this kind of a wage policy, what happens?

There seem to be two main cases. It is possible, in the first place, that the higher wage might be matched by a lower take-out. A lower take-out would raise the (real) wage-level that was consistent with double equilibrium; so the lower take-out should permit of the higher wage being attained without unemployment. So far, so good; it should however be noticed that if the course of the wage-level is established arbitrarily, fluctuations in take-out will probably be necessary in order to keep that arbitrary wage-level consistent with double equilibrium. The matter cannot be settled in this way once and for all.

Secondly, suppose that the higher wage-level is not matched by lower take-out. I do not think it can be doubted that this also is a practical problem. For when we remember how much of the consumable product of modern economies is "taken out" for social purposes, the demand for which comes from much the same source as the demand for higher wages, we must surely recognise that the alleviation which can come from lower take-out is likely to be limited. Say then that all that can be done in this direction has been done. Say also that saving-investment equilibrium is to be preserved. (It will not be easy to preserve it, but most of what is to be said under that head is well known; I need not enlarge upon it here.) What, under these conditions, will be the course of the economy?

The higher wage, as we have seen, will affect the techniques that are chosen for new investment; we may take it that they will, on the whole, be more capital-intensive than they would otherwise have been, at corresponding dates. Such techniques will in the end raise final output, *per unit of labour employed,* more than it would have been raised by less capital-intensive investment. But, all along, the volume of investment (in saving-investment equilibrium) will be lower than it would have been otherwise. Thus, although the economy is "aiming" at a steady state in which final consumable output, per unit of labour employed, is higher, employment along the path to that state (and—in principle—even in that final state) will be lower than it would have been. This, I now believe, is what I was trying to say in *Theory of Wages;* as will be seen, it is subject to many qualifications of which, when I wrote, I had no idea. But in substance the main point stands.

That it is possible for a "developing" country, by choice of techniques that are too capital-intensive, to expand employment in its "modern" sector less rapidly than it might have done, is nowadays familiar. What I am saying is little more than an application of that same principle.

[18]These ideas were not fully formed when I wrote *A Theory of Economic History* (1969), but I was working towards them.

Biographical Listing of Members

Biographies

Facsimile of Questionnaire

Classification Codes

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Residential customer response to time-of-use electric utility rates.

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MOUNT, RANDALL I, 7530 Skyview Dr, Kent, OH 44240. *Fields:* 020, 000. *Degrees:* Ph.D., Purdue U., 1959. *Prin. Cur. Position:* Kent State U.

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Dept., Fed. Reserve Bank of New York, 1972-81; Lectr., Fordham U., 1978–. *Research:* Financial institutions, monetary policy, micro theory.

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ZOFFER, H JEROME, 5620 Aylesboro Ave, Pittsburgh, PA 15217. *Phone:* Office (412)624-6410; Home (412)521-4014. *Fields:* 510, 010. *Birth Yr:* 1930. *Degrees:* B.B.A., U. of Pittsburgh, 1952; M.A., U. of Pittsburgh, 1953; Ph.D., U. of Pittsburgh, 1956. *Prin. Cur. Position:* Dean, Grad. Sch. of Bus., U. of Pittsburgh, 1968–. *Concurrent/Past Positions:* Assoc. Dean, Grad. Sch. of Bus., U. of Pittsburgh, 1965-68; Asst. Dean, Grad. Sch. of Bus., U. of Pittsburgh, 1962-65. *Research:* Risk & insurance; management education; future managerial environment.

ZOH, YOUNG JAE, 30 W. 061 Hurlingham Dr., No 502, Warrenville, IL 60555. *Phone:* Office (312)440-5858; Home (312)393-4274. *Fields:* 410, 310. *Birth Yr:* 1949. *Degrees:* B.A., Seoul Nat. U., 1972; B.S., Cornell U., 1977. *Prin. Cur. Position:* Grad. Student, U. of Chicago, 1977–. *Concurrent/Past Positions:* Assoc. Res. Econ., BCA & BSA, Chicago, 1980–.

ZOHAR, URI, York University, 4700 Keele St, Downsview, ON M3J 1P3, Canada. *Phone:* Office (416)667-3712; Home (416)782-1674. *Fields:* 110, 120. *Birth Yr:* 1931. *Degrees:* B.Sc., Calif. State Poly. U., 1964; M.A., Claremont Grad. Sch., 1967; Ph.D., Claremont Grad. Sch., 1967. *Prin. Cur. Position:* Prof. of Econs., Fac. of Admin. Studies, York U., 1969–. *Concurrent/Past Positions:* Lectr., Israel Institute of Technol., 1967-69; Sr. Lectr., Haifa U., 1967-69. *Research:* Productivity in manufacturing.

ZOHLNHOFER, WERNER, Bahnweg 33, Mainz 42, D-6500, West Germany. *Phone:* Office 06-131-392554; Home 06-131-59401. *Fields:* 610, 050. *Birth Yr:* 1934. *Degrees:* Dipl.Volks., U. of Freiburg, 1958; M.A., U. of N.C. at Chapel Hill, 1963; Dr.rer.Pol., U. of Freiburg, 1965; Dr.Habil., U. of Freiburg, 1972. *Prin. Cur. Position:* Prof., U. of Gutenberg, 1980–. *Concurrent/Past Positions:* Prof., U. of Dortmund, 1972-79. *Research:* Industrial orgn., antitrust, new political economy, policy-making.

ZOLOTH, BARBARA S, Dept. of Agr. Econs., U. of Calif., Davis, CA 95616. *Phone:* Office (916)752-1614; Home (916)758-4785. *Fields:* 850, 920. *Birth Yr:* 1943. *Degrees:* B.A., Brandeis U., 1965; Ph.D., U. of Minn., 1971. *Prin. Cur. Position:* Asst. Prof. of Agr. Econs., U. of Calif. at Davis, 1975–. *Concurrent/Past Positions:* Res. Assoc., Institute for Res. on Poverty, U. of Wis. at Madison, 1973-75; Brookings Economic Policy Fellow, U.S. Dept. of Health, Educ. & Welfare, 1972-73. *Research:* Economic roles of women in home and labor force.

ZONDAG, CORNELIUS H, 17512 Cumane Terrace, San Diego, CA 92128. *Phone:* Home (714)451-0222. *Fields:* 120, 630. *Birth Yr:* 1913. *Degrees:* Ph.D., Leyden U., 1940; M.A., New York U., 1949. *Prin. Cur. Position:* Int'l. Develop. Bus. Consult., Self-employed, 1975–. *Concurrent/Past Positions:* Adj. Prof., Ctr. for Latin Amer. Studies, Ariz. State U., 1975–; Econ., U.S. Dept. of State, 1954-74. *Research:* Latin American economic and social development.

ZOOK, CHRISTOPHER, 25 Skehan Rd, Belmont, MA 02178. *Phone:* Office (617)732-5787; Home (617)489-3054. *Fields:* 900, 210. *Birth Yr:* 1951. *Degrees:* B.A., Williams Coll., 1973; B.Phil., U. of Oxford, 1975; M.P.P., Harvard U., 1977. *Prin. Cur. Position:* Res. Fellow, Harvard U.

ZOOK, PAUL D, Sch. of Bus. Admin., U. of Tex., El Paso, TX 79999. *Phone:* Office (915)747-5244; Home (915)544-5195. *Fields:* 100, 400. *Degrees:* B.A., Goshen Coll., 1934; M.A., U. of Ill., 1940; Ph.D., U. of Ill., 1954. *Prin. Cur. Position:* Prof., U. of Tex. at El Paso, 1970–.

ZORN, CHARLES KURT, Sch. of Pub. & Environmental Affairs, Ind. U. at Bloomington, Bloomington, IN 47405. *Phone:* Office (812)337-0731; Home (812)333-8357. *Fields:* 320, 930. *Birth Yr:* 1954. *Degrees:* B.A., SUNY at Albany, 1976; M.A., Syracuse U., 1978; Ph.D., Syracuse U. *Prin. Cur. Position:* Ind. U. at Bloomington, 1980–. *Research:* Local revenue forecasting, municipal debt, housing.

ZORN, EUGENE C, Republic Nat. Bank of Dallas, P.O. Box 225961, Dallas, TX 75265. *Phone:* Office (214)653-5581; Home (214)368-5371. *Fields:* 310, 010. *Birth Yr:* 1916. *Degrees:* B.B.A., Bernard M. Baruch Coll. of CUNY, 1937; M.S., Columbia U., 1942. *Prin. Cur. Position:* Sr. V.Pres. & Econ., Republic Nat. Bank of Dallas, 1960–. *Concurrent/Past Positions:* Dir. of Res. & Dep. Mgr., Amer. Bankers Assn., 1940-60. *Research:* Bank economics.

ZORN, PETER M, Dept. of Econs., U. of Calif. at Davis, Davis, CA 95616. *Phone:* Office (916)752-2074; Home (916)758-3060. *Fields:* 930, 610. *Birth Yr:* 1953. *Degrees:* B.A., Marlboro Coll.; M.A., U. of Calif. at Davis. *Prin. Cur. Position:* Grad. Student, U. of Calif. at Davis.

ZORN, THOMAS S, Dept. of Fin., U. of Nebr. at Lincoln, Lincoln, NB. *Fields:* 610, 520. *Birth Yr:* 1940. *Degrees:* B.A., U. of Calif. at Los Angeles, 1964; M.A., U. of Calif. at Los Angeles, 1970; Ph.D., U. of Calif. at Los Angeles, 1978. *Prin. Cur. Position:* Asst. Prof. of Fin., U. of Nebr. at Lincoln, 1981–. *Concurrent/Past Positions:* Asst. Prof., U. of Ariz., 1978-81. *Research:* Economics of information.

ZSCHOCK, DIETER K, 2 Black Duck Dr., Stony Brook, NY 11790. *Phone:* Office (516)246-6174; Home (516)751-4851. *Fields:* 110, 810. *Birth Yr:* 1936. *Degrees:* B.A., Wesleyan U., 1962; Ph.D., Fletcher Sch. of Law & Diplomacy, Tufts U., 1967. *Prin. Cur. Position:* Assoc. Prof. of Econs. & Dir. of M.A. Prog. in Economic Policy, SUNY at Stony Brook, 1970–. *Concurrent/Past Positions:* Dir. of Economic Res. Bur., SUNY at Stony Brook, 1967-70; Res. Econ., Princeton U., 1972-73. *Research:* Health care financing, employment and training in developing countries.

ZSOLDOS, LASZLO, Coll. of Bus. & Econs., U. of Delaware, Newark, DE 19711. *Phone:* Office (302)738-2564; Home (302)731-4207. *Fields:* 430, 420. *Birth Yr:* 1925. *Degrees:* A.B., U. of Cincinnati, 1952; M.A., U. of Cincinnati, 1955; Ph.D., Ohio State U., 1961. *Prin. Cur. Position:* Prof. of Econs., U. of Delaware, 1968–. *Concurrent/Past Positions:* Assoc. Prof., U. of Del., 1964-68; Asst. Prof., U. of Ky., 1960-64. *Research:* International monetary markets and processes.

ZUBERI, HABIB A, Dept. of Econs., 310 Sloan Hall, Central Mich. U., Mt Pleasant, MI 48859. *Phone:* Office (517)774-3706; Home (517)773-2551. *Fields:* 300, 120. *Degrees:* M.A., Muslim U., 1963; M.S., Southern Ill. U., 1962; Ph.D., Southern Ill. U., 1971. *Prin. Cur. Position:* Chair, Dept. of Econs., Central Mich. U., 1980–. *Concurrent/Past Positions:* Assoc. Prof., Central Mich. U., 1967-80; Asst. Prof., Ball State U., 1965-67. *Research:* Institutional credit and economic deveopment.

ZUBKOFF, MICHAEL, 15 Ropeferry Rd, Hanover, NH 03755. *Phone:* Office (603)646-3422. *Fields:* 910, 810. *Birth Yr:* 1944. *Degrees:* M.A., Columbia U., 1966; Ph.D., Columbia U., 1969. *Prin. Cur. Position:* Prof. of Econs., Amos Tuck Sch. of Bus., Dartmouth Coll., 1975–. *Concurrent/Past Positions:* Chair, Community & Family Medicine, Dartmouth Medical Sch., 1975–; Instr. of Econs., Columbia U., 1967-69. *Research:* Health economics.

ZUBROW, REUBEN A, 300 Bellevue Dr, Boulder, CO 80302. *Phone:* Office (303)492-7928; Home (303)443-4092. *Fields:* 320, 930. *Birth Yr:* 1914. *Degrees:* B.S., Trenton State Coll., 1936; M.A., U. of Pa., 1940; Ph.D., Ind. U. at Bloomington, 1950. *Prin. Cur. Position:* Prof. of Econs., U. of Colo. at Boulder, 1949–. *Concurrent/Past Positions:* Instr., Ind. U. at Bloomington, 1946-49; Res. Econ., U.S. Off. of Price Admin., 1942-46. *Research:* State and local finance, public economics.

ZUCKER, ALBERT, Bernard M. Baruch Coll. of CUNY, 17 Lexington Ave, New York, NY 10010. *Phone:* Office (212)725-3164; Home (212)721-7380. *Fields:* 820, 210. *Birth Yr:* 1931. *Degrees:* B.S., City Coll. of CUNY, 1952; M.A., CUNY Grad. Sch. & U. Ctr., 1954; Ph.D., Columbia U., 1970. *Prin. Cur. Position:* Assoc. Prof., Bernard M. Baruch Coll. of CUNY, 1962–. *Research:* Economic effects of minimum wages.

ZUCKERMAN, ALAN M, 2316 Waverly St, Philadelphia, PA 19146. *Phone:* Office (215)972-0937; Home (215)735-2087. *Fields:* 910, 930. *Birth Yr:* 1950. *Degrees:* B.A., SUNY at Stony Brook, 1970; M.A., SUNY at Stony Brook, 1972. *Prin. Cur. Position:* Sr. Consult., Agnew Peckham & Assoc., 1980–. *Concurrent/Past Positions:* V.Pres., Hospital Survey Comn., 1973-80; Res. Assoc., Brookhaven Memorial Hospital, 1972-73. *Research:* Health economics.

ZUCKERMAN, IRVING, 2121 P St., N.W., Apt. 530, Washington, DC 20037.

ZUCKERMAN, STEPHEN, 435 W. 119th St., Apt.2H, New York, NY 10027. *Fields:* 800, 210. *Birth Yr:* 1954. *Degrees:* B.A., Herbert H. Lehman Coll. of CUNY, 1975; M.A., Columbia U., 1977; M.Phil., Columbia U., 1979. *Prin. Cur. Position:* Grad. Student, Columbia U., 1975–. *Research:* Job search models wth variable search effort.

ZUIDEMA, R P, Elzenlaan 50, Hilversum 1214 KM, The Netherlands. *Fields:* 020, 900. *Birth Yr:* 1939. *Degrees:* Master, Free U. of Amsterdam, 1964; Dr., Free U. of Amsterdam, 1970. *Prin. Cur. Position:* Prof., Free U. of Amsterdam, 1980–. *Concurrent/Past Positions:* Assoc. Prof., Free U. of Amsterdam, 1971-79. *Research:* Micro-economics and welfare economics.

ZUKOWSKI, WALTER H, Colby College, Waterville, ME 04901. *Fields:* 520, 510. *Degrees:* B.B.A., Clark U., 1948; M.A., Clark U., 1949; Ph.D., Clark U., 1956. *Prin. Cur. Position:* Wadsworth Prof. of Admin. Sci., Colby Coll., 1973–. *Concurrent/Past Positions:* Vis. Prof., Robert Coll., Istanbul, 1972-73; Vis. Prof., Robert Coll., Istanbul, Turkey, 1965-66.

ZULLI, DAVID M, 11322 Missouri Ave., #6, Los Angeles, CA 90025.

ZUMBURS, GEORGE, 2144 Garry Dr, Troy, MI 48084. *Phone:* Office (313)876-5480; Home (313)689-1576. *Fields:* 810, 820. *Birth Yr:* 1948. *Degrees:* B.S., Mich. State U., 1970; M.A., Western Mich. U., 1975. *Prin. Cur. Position:* Economic Analyst, Dept. of Labor, State of Mich. *Research:* Labor market analysis, current employment statistics program.

ZUPNICK, ELLIOT, 5550 Fieldston Rd, Riverdale, NY 10471. *Phone:* Office (212)280-5400; Home (212)549-7574. *Fields:* 400, 300. *Birth Yr:* 1923. *Degrees:* B.S.S., City Coll. of CUNY, 1947; M.A., Columbia U., 1949; Ph.D., Columbia U., 1954. *Prin. Cur. Position:* Prof. of Econs., Columbia U., 1979–. *Concurrent/Past Positions:* Dean of Grad. Studies, CUNY Grad. Sch. & U. Ctr., 1969-72; Instr. to Prof., CUNY Grad. Sch. & U. Ctr., 1951-69. *Research:* International monetary problems.

ZURASKI, ROBERT, 1425 Fourth St., S.W., Apt. A-715, Washington, DC 20024. *Phone:* Office (202)223-1700; Home (202)554-0855. *Fields:* 130, 300. *Birth Yr:* 1949. *Degrees:* B.A., U. of Conn. at Storrs, 1971; M.A., Syracuse U., 1975. *Prin. Cur. Position:* Consult., Coopers & Lybrand, 1981–. *Concurrent/Past Positions:* Institute for Res. on Econs. of Taxation, 1980-81; Norman B. Ture, Inc., 1980-81.

ZUSMAN, PINHAS, Dept. of Agr. Econs., Fac of Agriculture, Rehovot, Israel. *Phone:* Office 054-81231; Home 054-73549. *Fields:* 210, 050. *Birth Yr:* 1927. *Degrees:* M.A., U. of Calif. at Berkeley, 1960; Ph.D., U. of Calif. at Berkeley, 1961. *Prin. Cur. Position:* Prof., Hebrew U. at Rehovot, 1961–. *Research:* Agricultural cooperatives and contract theory.

ZUTZ, WERNER, Mueller Str. 33, Berlin 45, D-1000, West Germany. *Phone:* Office 030-881-3016; Home 030-621-8531. *Fields:* 540, 300. *Birth Yr:* 1951. *Degrees:* Dipl.Kfm., Free U. of Berlin, 1980. *Prin. Cur. Position:* Auditor Asst., Treuverkehr AG, 1981–. *Research:* Bank rendering of account, inflation theory.

ZUVEKAS, CLARENCE, 4215 N. Valiant Ct., Annandale, VA 22003. *Phone:* Office (202)632-1737; Home (703)978-2554. *Fields:* 110, 120. *Birth Yr:* 1941. *Degrees:* B.A., Johns Hopkins U., 1961; Ph.D., Washington U., 1967. *Prin. Cur. Position:* Econ., U.S. Agency for Int'l. Develop., 1979–. *Concurrent/Past Positions:* Assoc. Prof. of Econs., Moorhead State U., 1971-76; Economic Advr., U.S. Agency for Int'l. Develop., 1966-71. *Research:* Employment, income distribution & land tenure in developing countries.

ZWECHER, MICHAEL J, 17 Irving Rd, Natick, MA 01760. *Degrees:* B.A., Framingham State Coll., 1979; M.A., Tufts U., 1981. *Prin. Cur. Position:* Student, U. of Wis. at Madison, 1981–. *Concurrent/Past Positions:* Academic Serv. Coordr., Tufts U., 1980-81; Teaching Asst., Tufts U., 1979-81.

ZWERNEMAN, JAMES A, P.O. Box 741, Notre Dame, IN 46556. *Phone:* Office (219)234-2228; Home (219)272-1838. *Fields:* 130, 520. *Birth Yr:* 1927. *Degrees:* A.B., Stanford U., 1950; A.M., Stanford U., 1959; Ph.D., U. of Notre Dame, 1966. *Prin. Cur. Position:* Pres., Speira, Inc. *Concurrent/Past Positions:* Dir., Ctr. for Bus. Serv., N.Mex. State U., 1971-77; Chair, Dept. of Econs., N.Mex. State U., 1972-74. *Research:* Market research, enterprise development.

ZWEZERINJNEN, W J, Slotstraat 19, Beesd Leerdam, The Netherlands.

ZWICK, BURTON, Prudential Insurance Co, Prudential Plaza, 13th Floor, Newark, NJ 07101. *Prin. Cur. Position:* Economic & Investment Res., Prudential Ins. Co.

ZYCHER, BENJ, Council of Economic Advr., Old Exec. Off. Bldg., Washington, DC 20506. *Phone:* Office (202)395-5108; Home (213)347-9038. *Fields:* 610. *Birth Yr:* 1950. *Degrees:* A.B., U.of Calif. at Los Angeles, 1972; M.P.P., U. of Calif. at Berkeley, 1974; M.A., U. of Calif. at Los Angeles, 1978; Ph.D., U. of Calif. at Los Angeles, 1979. *Prin. Cur. Position:* Sr. Staff Econ., Council of Economic Advr., 1981–. *Concurrent/Past Positions:* Sr. Econ., The Econs. Group, 1980-81; Sr. Analyst, Nat. Res. Assoc., 1979-80. *Research:* Energy policy, general microeconomic policy analysis.

ZYSKOWSKI, WILLIAM, 1907 E Oakdale St, Philadelphia, PA 19125.

AMERICAN ECONOMIC ASSOCIATION

THE INFORMATION REQUESTED WILL BE USED TO PREPARE YOUR ENTRY IN THE 1981 AMERICAN ECONOMIC ASSOCIATION *SURVEY OF MEMBERS.* INFORMATION PRESENTLY ON RECORD FOR YOU FROM THE PREVIOUS DIRECTORY SURVEY IS PRE-PRINTED ON THE QUESTIONNAIRE. DRAW A LINE THRU ITEMS TO BE DELETED AND ENTER THE NEW OR CORRECTED INFORMATION IN THE BLANK LINE DIRECTLY BELOW EACH ITEM. MAIL YOUR COMPLETED QUESTIONNAIRE IN THE ENCLOSED RETURN ENVELOPE.

SEE FURTHER INSTRUCTIONS PRINTED ON REVERSE SIDE.

AREA CODE

AREA CODE

ANSWERS MUST BE LIMITED TO SPACE PROVIDED

LAST NAME | FIRST NAME OR INITIAL | MIDDLE NAME OR INITIAL

SECOND SURNAME FOR CROSS-LISTING

A. B.

CITY | U.S. STATE | U.S. ZIP CODE

NON U.S. ONLY

FOREIGN POSTAL CODE | CITY | PROVINCE | COUNTRY

TITLE | INSTITUTION OR FIRM

BEFORE YOU ANSWER ITEMS 7, 9 & 10, PLEASE REREAD INSTRUCTIONS ON REVERSE SIDE.

LOCATION OR CAMPUS | FROM YEAR

TITLE | INSTITUTION OR FIRM | LOCATION OR CAMPUS | FROM YEAR | TO YEAR

TITLE | INSTITUTION OR FIRM | LOCATION OR CAMPUS | FROM YEAR | TO YEAR

With increasing frequency, the Association is asked about the numbers of economists who are members of various groups. Please help by answering the following questions. **YOUR RESPONSE WILL NOT APPEAR IN THE *SURVEY*.**

12 OPTIONAL STATISTICAL DATA

COUNTRY OF BIRTH	CITIZENSHIP	SEX	RACIAL BACKGROUND	IS YOUR ETHNIC HERITAGE HISPANIC?
U.S.A.	U.S.A.	MALE	ASIAN	YES
OTHER_____	OTHER_____	FEMALE	BLACK	NO
			WHITE	
			OTHER_____	

SAMPLE

AEA *SURVEY OF MEMBERS*

Please read these instructions before completing the Questionnaire

This questionnaire contains the information currently on record for you. The information as shown on the questionnaire will be published in the next *Survey* unless the form is returned with corrections or new information. You must be a current member in June 1981 to be included in the *Survey*.

GENERAL INSTRUCTIONS

- Print or write legibly and please avoid writing in the shaded boxes. Existing information is pre-printed in the shaded lines.
- Please answer all questions that apply to your situation. Information which you do not wish to have published should be deleted or omitted.
- Limit your responses to the requested items and enter the information in the designated spaces.
- Do not attach your vita in lieu of completing the questionnaire. Only information legibly entered in the designated spaces will be used.
- PLEASE RETURN THE QUESTIONNAIRE IN THE ENCLOSED ENVELOPE. Your early response will aid in reducing survey processing costs and assure inclusion of your updated listing in the *Survey*.

SURVEY INFORMATION

(Questions 1 thru 12)

1. NAME. Your name as preferred for *Survey* publication. Please do not use titles. If you wish to be cross-listed under second surname, please enter it in the appropriate space.

2. ADDRESS. This is the address to which your AEA journals are being sent. Correcting this address does not automatically change the AEA mailing list. Please notify the secretary's office of all address changes.

3. OFFICE AND HOME PHONE. Enter your current office and home telephone area-code and numbers.

4. MAJOR FIELDS. Select your two most important specialty areas from Code List A and enter the 3-digit codes on the questionnaire. Give preference to subdivisions over main divisions (e.g. if you are primarily a demographer, insert the number "840" for "Demographic economics", rather than "800" for "Manpower; Labor; Population").

LIST A

FIELDS

000 General economics; Theory; History; Systems
- 010 General economics
- 020 General economic theory
- 030 History of thought, methodology
- 040 Economic history
- 050 Economic systems
- 060 Economic education

100 Economic growth; Development; Planning; Fluctuations
- 110 Economic growth, development, and planning theory and policy
- 120 Economic development studies
- 130 Economic fluctuations, forecasting, and inflation

200 Economic statistics
- 210 Econometric, statistical, and mathematical methods and models
- 220 Economic and social statistics

300 Monetary and fiscal theory and institutions
- 310 Domestic monetary and financial theory and institutions
- 320 Domestic fiscal policy and public finance

400 International economics
- 410 International trade theory
- 420 Trade relations, commercial policy, economic integration
- 430 Balance of payments, international finance
- 440 International investment and foreign aid

500 Administration; Business finance; Marketing; Accounting
- 510 Administration
- 520 Business finance and investment
- 530 Marketing
- 540 Accounting

600 Industrial organization; Technological change; Industry studies
- 610 Industrial organization and public policy
- 620 Economics of technological change
- 630 Industrial studies
- 640 Economic capacity

700 Agriculture; Natural resources
- 710 Agriculture
- 720 Natural resources
- 730 Economic geography

800 Manpower; Labor; Population
- 810 Manpower training and allocation, labor force and supply
- 820 Labor markets, public policy
- 830 Trade unions, collective bargaining, labor-management relations
- 840 Demographic economics
- 850 Human capital

900 Welfare programs; Consumer economics; Urban and regional economics
- 910 Welfare programs
- 920 Consumer economics
- 930 Urban economics
- 940 Regional economics

A00 Related Disciplines

5. YEAR OF BIRTH. Enter your year of birth.

6. EARNED DEGREES. List your earned degrees in chronological order, showing the year, the degree name and the granting institution's name. If you have more than one degree of equal level, list the second degree. Please use the standard abbreviation for the degree name. Include the institution branch or location along with the institution name.

7. PRINCIPAL PRESENT EMPLOYMENT. Enter the proper name of your employer and your present position title. Include the institution branch or campus to clarify your affiliation. Self-employed or Retired may be entered in place of an institution or firm name. Graduate Student, Teaching Assistant or Research Assistant may be used as position titles when applicable. Retired or semi-retired members are urged to return the questionnaire indicating their emeritus or retired status. Current work activities, if any, can be listed in questions 9 & 10.

8. Enter code from Code List B.

LIST B

Employment Codes

Academic
- 01 Two-Year College
- 02 Four-Year College
- 03 University
- 04 Other educational institution

Non-academic
- 10 Federal Government
- 20 State/Local Government
- 30 Business/Industry
- 40 Banking/Finance
- 50 Consulting
- 60 International Agency or Organization
- 70 Research Institution
- 80 Non-profit Organizations other than educational and research
- 90 Retired
- 99 Other

9. OTHER PRESENT OR PAST EMPLOYMENT. These two items may be used as desired to list additional present positions and/or past employment. A previous position is indicated by entry of the FROM and TO years. If only the FROM year is listed, the position will be treated as a present employment. Indicate a position beginning and ending in the same year by entering the year twice, e.g. ('76'76). Only two positions in addition to your principal present employment will be listed.

11. In 10 words or less indicate your current area of research interest.

12. OPTIONAL STATISTICAL DATA. With increasing frequency, the Association is asked about the numbers of economists who are members of various groups. Please help by answering the questions. Your response will NOT appear in the *Survey*.

Classification Codes for Fields of Specialization

000 General Economics; Theory; History; Systems
- 010 General economics
- 020 General economics theory
- 030 History of thought, methodology
- 040 Economic history
- 050 Economic systems
- 060 Economic education

100 Economic growth; Development; Planning; Fluctuations
- 110 Economic growth, development, and planning theory and policy
- 120 Economic development studies
- 130 Economic fluctuations, forecasting, and inflation

200 Economic statistics
- 210 Econometric, statistical, and mathematical methods and models
- 220 Economic and social statistics

300 Monetary and fiscal theory and institutions
- 310 Domestic monetary and financial theory and institutions
- 320 Domestic fiscal policy and public finance

400 International economics
- 410 International trade theory
- 420 Trade relations, commercial policy, economic integration
- 430 Balance of payments, international finance
- 440 International investment and foreign aid

500 Administration; Business finance; Marketing; Accounting
- 510 Administration
- 520 Business finance and investment
- 530 Marketing
- 540 Accounting

600 Industrial organization; Technological change; Industry studies
- 610 Industrial organization and public policy
- 620 Economics of technological change
- 630 Industrial studies
- 640 Economic capacity

700 Agriculture; Natural resources
- 710 Agriculture
- 720 Natural resources
- 730 Economic geography

800 Manpower; Labor; Population
- 810 Manpower training and allocation, labor force and supply
- 820 Labor markets, public policy
- 830 Trade unions, collective bargaining, labor-management relations
- 840 Demographic economics
- 850 Human capital

900 Welfare programs; Consumer economics; Urban and regional economics
- 910 Welfare programs
- 920 Consumer economics
- 930 Urban economics
- 940 Regional economics

A00 Related Disciplines

Classification of Members by

Fields of Specialization

Academic Affiliation

Classification of Members by Fields of Specialization

000 GENERAL ECONOMICS; THEORY; HISTORY; SYSTEMS

010 GENERAL ECONOMICS
020 GENERAL ECONOMICS THEORY
030 HISTORY OF THOUGHT, METHODOLOGY
040 ECONOMIC HISTORY
050 ECONOMIC SYSTEMS
060 ECONOMIC EDUCATION

Abel, T. E. 030, 620
Abele, H. 020, 310
Abner, C. E. 030, 430
Abouchar, A. 050, 900
Ackley, S. W. 010, 040
Acs, Z. J. 000, 020
Adam, J. 050, 810
Adams, C. H. 020, 410
Adams, C. H. 000, 810
Adams, E. T. 020, 320
Adams, J. D. 020, 820
Adams, W. H., III 010, 020
Adelshem, P. D. 000, 610
Adesalu, J. B. 020
Adjami, H. 000, 500
Adler-Karlsson, G. 050, 110
Agapos, A. M. 020, 310
Agnew, C. E. 020, 600
Agor, E. C. 030, 710
Ahmad, S. 020, 310
Ahn, K. 020, 310
Akat, A. S. 020, 110
Akerblad, G. E. 000, 120
Alban, E. 020, 210
Albert, H. 030, 050
Albert, L. H. 050, 110
Albert, S. H. 020, 720
Albin, P. S. 020, 110
Albrecht, G. V. 020, 320
Aldrich, C. A. 020, 900
Alexander, A. P. 020, 510
Alexeev, M. V. 050, 210
Alger, D. R. 020, 600
Allerta, M. 020, 310
Allais, M. 020, 130
Allen, B. E. 020, 210
Allen, F. 020, 320
Allen-Schult, E. 020
Allingham, M. 020
Alsadi, A. 010, 110
Alston, L. J. 040
Altazan, J. E. 040, 410
Ambirajan, S. 030, 040
Amihud, Y. 020, 520
Amir, S. 020, 720
Anderson, A. D. 040, 930
Anderson, B. W. 020, 810
Anderson, D. W. 010, 210
Anderson, L. D. 040, 930
Anderson, M. 010, 910
Anderson, R. E. 020, 720
Ando, A. K. 020, 210
Ando, F. H. 010, 320
Andrews, C. H. 020, 600
Andvig, J. C. 030, 050
Angressano, J. W. 030, 120
Angulano, E. 010, 420
Ankil, R. E. 040, 430
Anon, N. S. 060, 040
Anspach, R. 030, 010
Anthes, W. L. 010, 930
Aoki, M. 020, 050
Appelbaum, E. R. 020, 810
Arasmith, L. L. 020, 400
Arcelli, M. 020, 310
Archibald, G. C. 010
Arden, R. S. 010, 210
Arkan, O. S. 010, 440
Armstrong, R. 040, 720
Arnott, R. J. 020, 930
Arouh, A. A. 030, 010
Arrow, K. J. 020, 110
Arsenovich, D. 020, 940
Arvan, L. D. 020, 010
Asako, K. 020, 310
Asano, K. 020, 030
Ashbrook, A. G., Jr 050, 020
Ashby, D. B. 020, 300
Asher, R. 010, 110
Ashley, J. W. 010, 060
Atack, J. 040, 620
Atkinson, F. M. 040, 120
Atkinson, L. C. 020, 300
Atkinson, S. N. 030
August, J. D. 010, 130
Augusta, L. 010, 060
Auster, N. R. 010, 840
Auster, R. D. 020, A00
Auten, J. H. 010, 310
Avenell, S. 030, 110
Averitt, G. R. 010, 610
Avin, A. 020, 520
Awh, R. Y. 020, 220
Axelson, D. J. 060, 730
Ayres, M. E. 060, 030
Azqueta, D. 020, 400
Baack, B. 040, 110
Backhouse, R. E. 020, 030
Baer, J. W. 060, 110
Baer, W. 010, 540
Bagley, E. S. 020, 130
Bailey, E. E. 020, 610
Bailey, J. W. 010, 000
Bailey, M. P. F. 020, 030
Baird, J. M. 010, 630
Balestri, A. 030, 600
Balfour, B. B. 010, 700
Balinky, A. 050, 030
Ballantyne, A. P. 020, 430
Ballestero, E. 010, 510
Ballman, R. J. 010, 030
Ballot, G. O. 020, 210
Bandor, F. 040, 120
Bandyopadhyay, T. 020, 410
Baptie, R. H. 010, 710
Baqir, G. 030, 050
Barandiaran, E. E. 010, 130
Barbe, L. 020, 210
Barber, L. I. 040, 510
Barber, W. J. 030, 110
Barbour, J. L. 010, 030
Bardaro, J. 010, 300
Barden, D. S. 050, 210
Barkai, H. 030, 310
Barnett, B. C. 010
Barnett, E. V. 040, 110
Barnum, H. N. 020, 210
Baron, H. 040, 000
Baron, P. 010, 530
Barr, M. D. 020, 310
Barr, S. Z. 060, 210
Barrett, N. S. 020, 130
Barrows, D. S. 010, 510
Barry, B. M. 010, 440
Barry, R. A. 020, 130
Bartel, H. 020, 210
Barthel, J. E. 010, 200
Barthelemy, P. 020, 110
Barthold, T. A. 020, 610
Bartholomew, R. J. 010, 540
Bartmann, H. 020, 130
Barucci, P. 030, 940
Barzel, Y. 010, 000
Bassett, L. R. 020, 210
Bastien, R. 000, 600
Batchelder, R. W. 020, 320
Batlin, C. A. 020, 520
Bator, F. M. 020, 320
Battis, R. A. 050, 040
Batta, N. C. 010, A00
Bauge, K. L. 020, 210
Baumberger, J. P. 010, 310
Baumgard, G. 020, 310
Baumgartner, H. W. 050, 920
Baumgartner, T. 050, 400
Baumol, W. 020, 030
Baye, M. 020, 610
Beach, E. F. 020, 030
Bean, R. N. 040, 610
Bear, D. V. T. 020, 210
Bebchuk, L. A. 020
Becker, A. S. 050
Becker, G. S. 020, 850
Becker, R. A. 020, 110
Beckwith, B. P. 020, 050
Behar, A. 010, 130
Behr, M. 010, 940
Bellevesu, B. C. 020, 210
Bell, D. 050, 100
Bell, J. F. 030, 050
Bell, J. G. 010, 130
Bell, P. W. 020, 540
Bellia, C. 010, 040
Bellico, R. 010, 040
Bellia, A. M. 020, 630
Bellofiore, R. 030, 110
Benhabib, J. 020, 100
Bennett, E. 020, 210
Bentick, B. L. 020, 930
Berck, P. 020, 700
Berenyi, L. 030, 630
Berg, E. M. 040, 320
Berg, J. T. 020, 610
Bergson, A. 050, 020
Bergsten, G. S. 050, 030
Berliner, J. S. 050, 900
Berman, J. S. 010, 000
Bernard, K. E. 010, 220
Bernhardt, H. M. 050, 610
Bernstein, M. A. 040, 030
Berry, J. M. 010, 320
Berry, R. E. 010, 910
Berry, T. S. 040, 120
Berschauer, R. G. 010, 520
Betz, H. 030, 050
Bever, R. C. 010, 630
Bewley, T. F. 020
Bhattacharya, G. 020, 720
Bialik, D. M. 020, 060
Bierwag, G. O. 020, 520
Bilas, R. A. 020, 910
Bilkes, G. 010, 130
Binger, B. R. 020, 620
Bingham, R. C. 010, 060
Birch, J. W. 020, 210
Bird, R. E. 020, 030
Birtek, F. 040, 600
Bishop, R. L. 020, 030
Bissell, R. M. 020, 130
Bitros, G. C. 020, 210
Bittencourt, M. D. C. 030, 130
Bjornson, G. B. 020, 220
Black, D. A. 020, 810
Blackwell, J. L. 010, 210
Blair, D. H. 020
Blair, D. W. 020, 030
Blais, J. 060, 050
Blake, D. R. 020, 930
Blank, F. M. 020, 310
Blicksilver, J. 040, 110
Blin, J. M. 010, 210
Blitz, R. C. 040, 110
Blitzer, D. M. 010, 210
Block, H. 050, 110
Blocki, R. A. 010, 130
Blodgett, R. H. 020, 030
Blum, R. 000
Blyth, C. A. 030, 130
Bobbitt, P. B. 010, 040
Boddy, F. M. 020, 610
Bodenhorn, D. 020, 540
Boessmann, E. 020, 610
Bohm, P. J. G. 020, 110
Boland, L. A. 030, 020
Bold, F. C. 020, 200
Bolino, A. C. 040, 800
Bolton, C. J. 030, 050
Bombach, G. E. 020, 110
Bombelles, J. T. 000, 050
Bomberger, W. A. 020, 310
Boncher, W. H. 050, 020
Bond, M. S. 050, 040
Bone, M. W. 060, 020
Bonsor, T. W. 020, 040
Booth, D. R. 050, 020
Borchardt, K. 040, 010
Borcherding, T. E. 020, 320
Bordo, M. D. 040, 310
Borek, T. 010, 800
Bornemann, A. H. 020, 310
Bornstein, M. 050, 110
Boss, E. H., Jr 010, 310
Boss, H. H. 030, 050
Boss, I. S. 010, 040
Bostaph, S. 020, 030
Botwin, H. J. 030, 110
Bouknight, J. G. 010, 020
Boulding, K. E. 010, 720
Bour, J. L. 020, 210
Bourque, P. J. 010, 200
Bove, R. E. 010, 210
Bovet, E. D. 020, 130
Bowerman, P. V. 030, 050
Bowles, D. C. 020, 310
Bowles, W. D. 050, 120
Bowling, A. L. 010, 530
Bowman, D. O. 010, 110
Bowman, W. W. 010, 210
Boyer, M. 020, 110
Boyes, W. J. 020, 130
Brada, J. C. 050, 420
Bradfield, J. 020, 520
Bradford, C. H. 010, 320
Bradford, E. B. 020, 310
Bradley, J. H. 010, 060
Braff, A. J. 020, 030
Brainard, W. C. 020, 310
Braitterman, T. 000, 310
Brandis, R. 030, 020
Branti, C. M. S. 020, 310
Bray, M. M. 020, 620
Brazelton, W. R. 020, 050
Breckner, N. V. 010, 320
Brehm, C. T. 020, 610
Breit, W. L. 030, 610
Brems, H. J. 020, 110
Brenneke, J. S. 060, 920
Brenner, R. 000, 100
Bresser-Pereira, L. 010, 110
Brewton, A. R. 030, 210
Brezinski, H. D. 050, 420
Brink, H. 020, 030
Britto, R. 020, 110
Brocato, J. 020, 210
Bronfenbrenner, M. 020, 300
Brookins, O. T. 020, 310
Brooks, S. 030, 610
Broude, H. W. 040, 610
Broughman, S. P. 050, 800
Broussalian, V. L. 010, 320
Brown, B. W. 020, 800
Brown, E. K. 030, 310
Brown, P. L. 020, 610
Brown, S. R. 040, 050
Brown, W. S. 020, 030
Browne, M. S. 030, 410
Browning, S. C. 000, 700
Brumm, H. J. 010, 820
Brunhild, G. 020, 300
Brunton, B. G. 040, 050
Bruschke, H. H. 020, 320
Bruyn-Hundt, M. 020
Bryant, R. R. 020, 720
Bryson, P. J. 050, 030
Brzeski, A. 050, 110
Buck, M. A. 040, 310
Buechner, M. N. 030, 320
Buhr, W. 020, 940
Bungum, J. L. 030, 400
Bunting, J. W. 010, 310
Bunting, R. L. 010, 310
Burch, S. W. 010, 130
Burdine, F. B. 040, 940
Burke, G. 010, 320
Burkett, J. P. 050, 400
Burmeister, E. 020, 210
Burns, A. E. 030, 520
Burns, E. J. 010, 030
Bush, P. D. 020, 030
Butler, M. W. 020, 300
Butos, W. N. 030, 310
Butters, G. R. 020, 610
Buxton, H. C. 010, 630
Byatt, I. C. R. 000, 900
Byers, N. F. 030, 220
Byrne, T. E. 010, 050
Caballero, F. 020, 210
Cabe, R. A. 020, 720
Cafiero, A. F. 010
Cahill, J. M. 010, 040
Cain, J. P. 020, 830
Cain, L. P. 040, 930
Caldwell, B. J. 030, 020
Caldwell, E. L. 010, 110
Calkins, R. N. 010, 220
Camacho, A. 020, 050
Cameron, C. 020, 310
Cameron, R. 040, 120
Campagna, A. S. 020, 320
Campbell, H. S. 010, 930
Campbell, R. 030, 850
Campbell, R. B. 010, 710
Campbell, R. W. 050, 110
Campbell, W. F. 030, 040
Canavese, A. J. 020, 100
Candelario, C. 020, 210
Canes, M. E. 010, 610
Canterbery, E. R. 020, 430
Canto, V. A. 020, 000
Cantor, A. B. 010, 320
Capelli, G. 020, 600
Capuzzo, A. 050, 310
Caravale, G. A. 020, 030
Carbaugh, D. C. 020, 030
Carle, S. 020, 820
Carlson, L. A. 040, 810
Carlsson, E. H. 020, 210
Carlton, D. W. 020, 600
Carman, J. R. 010, 210
Carneiro-Netto, D. 010, 020
Carney, F. J. 040, 840
Caro, J. Y. 020, 030
Caron, J. F. 010, 020
Carothers, R. L. 020, 410
Carr, D. W. 000, 610
Carroll, T. M. 020
Carroll, W. D. 020, 820
Cartea, M. J. 030, 720
Carter, G. H. 020, 940
Carter, J. R. 020, 410
Carter, M. G. 020, 820
Carter, S. B. 040, 820
Casanova, J. 010, 420
Case, E. G. 010, 120
Casper, C. A. 020, 620
Casperson, L. J. 040, 120
Cassel, D. 050, 010
Castorina, C. P. 030, 040
Castro, A. A. 040, 400
Catala, F. A. 050, 110
Catsoulis, C. 030, 310
Cave, M. 050, 110
Chaigian, C. 010, 020
Chamberlain, W. C. 020, 400
Chamberlin, J. R. 020, 210
Chan, K. P. 020, 210
Chan, L. K. 020, 210
Chand, M. 020, 210
Chang, J. L. Y. 000, 100
Chang, M. L. 020, 320
Chang, S. S. 010, 110
Chao, K. 050, 120
Chapman, J. G. 050, 820
Chappell, H. W., Jr 000, 600
Chase, E. P., III 020, 520
Chase, R. X. 030, 020
Chastain, E. D. 020, 110
Chavrid, A. V. 010, 930
Chawluk, A. 050, 420
Chen, C. T. 020, 630

Chen, F. S. 020, 030
Chenault, L. 020, 210
Cheng, B. S. 020, 800
Cheng, C. 050, 120
Cheng, G. D. 000, 400
Cheng, L. K. H. 020, 410
Chernomas, R. J. 020, 030
Cherry, R. 020, 800
Cheung, S. N. S. 020, 000
Chew, S. H. 020, 010
Chichilnisky, G. 020, 410
Childs, R. N. 040, 630
Chilton, J. B. 020, 610
Chirinko, R. S. 000, 210
Chitwood, J. C. 030, 510
Cho, W. 020, 840
Cho, Y. 020, 310
Choi, E. K. 020, 410
Choi, J. P. 020, 210
Cholewicki, V. 020, 110
Choudhury, P. 010, 710
Chowdhury, A. S. 020, 110
Christian, V. L. 020, 820
Christiansen, D. S. 020, 210
Christofides, L. N. 010, 020
Chu, K. 020, 210
Clava, A. 020, 310
Ciesla, C. S. 020, 210
Cirillo, R. 020, 030
Cizakca, M. 040
Clark, B. S. 030, 050
Clark, J. R. 010, 320
Clark, M. G. 050, 810
Clark, W. W. 030, 010
Clarke, R. N. 020, 610
Clayton, E. M. 050, 710
Cleaver, T. W. 040, 940
Clements, K. W. 010
Clotfelter, C. P. 020, 220
Clower, R. W. 020, 610
Cluff, L. D. 020, 310
Coase, R. H. 020, 610
Cochrane, D. 010, 110
Cochrane, J. L. 020, 030
Coelho, P. 040, 020
Coene, P. R. 020, 820
Coes, D. V. 020, 410
Cohen, J. S. 040, 850
Cohen, S. I. 020, 210
Cohn, R. L. 040, 210
Colander, D. C. 020, 320
Colberg, M. R. 020, 910
Cole, C. L. 030, 610
Cole, K. R. 010
Coleman, J. S. 010, 020
Colin, D. H. 010, 830
Collado, J. C. 020, 210
Collery, A. 020, 430
Collier, C. F. 030, 000
Collier, I. L. 050, 040
Collins, W. D. 020, 610
Congelton, R. D. 010, 320
Conley, B. C. 020, 520
Conlisk, J. 010, 210
Conn, D. A. 020, 050
Conrad, K. 020, 210
Constantacopoulos, G. C. 050, 120
Converse, R. 050, 130
Cook, E. J. 020, 030
Copeland, M. A. 020, 220
Cordoni, M. L. 010, 320
Coslmano, T. F. 010, 030
Costrell, R. M. 020, 130
Cots, D. O. 010, 710
Cothren, R. D. 020, 310
Coultar, L. A. 010, 060
Coupe, J. D. 020, 210
Cover, V. D. 010, 420
Cox, J. B. 020, 400
Coy, D. 010, 830
Crafton, S. M. 020, 610
Cramer, D. L. 030, 410
Crawford, J. C. 010, 020
Crawford, J. L. 020, 060
Crawford, M. M. 020, 010
Creek, J. W. 010, 310
Crews, R. M. 020, 840
Crocker, T. N. 010, 830
Crook, D. 010, 400
Cross, J. G. 020, 000
Cruces, E. 010, 540
Culbertson, J. M. 020, 030
Cummings, R. J. 020
Curry, D. S. 020, 430
Curtis, F. J. 010, 820
Curtis, T. D. 030, 830
Cyert, R. M. 020, 610
Dasne, J. D. 000, 400
Dacey, R. 030, 210
Decy, D. C. 010, 310
Dadd, M. 010, 710
D'Adda, C. 010, 310
Dadzie, B. 020, 120
Daka, L. E. 010, 050
Dalgaard, B. R. 040, 060
Dalton, E. F. 020, 110
Daly, G. G. 000, 600
Damus, S. 010, 310
Danner, P. L. 040, A00
Danziger, L. 020, 820
Darrough, M. N. 020, 920
Dauhajre, A. S. 020, 400
Dauterive, J. W. 010, 220
David, P. A. 040, 620
Davidson, G. E. 010, 020
Davidson, L. S. 010, 310
Davidson, R. K. 020, 120
Davies, G. K. 010, 210
Davis, C. M. 050, 210
Davis, E. 010, 030
Davis, L. E. 040, 110
Davis, O. A. 010, 900
Davis, R. A. 030, 110
Davis, R. M. 020, 030
Davis, T. J. 020, 030
Dawson, G. G. 010, 060
Day, R. H. 020, 100
Dayan, D. 010, 210
Deslessi, L. 020, 050
Dean, C. R. 010
Dean, S. E. 010, 420
Deandrea, V. 020, 040
Deans, R. H. 020, 120
Debreu, G. 020
Debruyne, G. 020, 210
Decanio, S. J. 040, 210
de Capriles, M. A. 000, 540
Dechert, W. D. 020, 210
Deeb, M. F. 010, 310
De La Vinelle, L. D. 050, 110
Delorme, C. D. 020, 310
de Marchi, N. B. 030, 310
Demmert, H. G. 010, 610
Demopoulos, G. D. 020, 300
Demuth, C. C. 010
Dennen, R. T. 020, 910
Dennis, E. 023, 210
Denny, M. G. S. 020, 210
Denta, L. A. 030, 020
Depablo, J. C. 020, 130
Dernberger, R. F. 050, 120
De Schweinitz, K. 050, 120
Deserpa, A. C. 020, 610
Despain, L. K. 010, 530
Devany, A. S. 020, 640
Devarajan, S. 020, 110
Diamond, A. M. 030, 850
Diamond, D. E. 040, 810
Diamond, J. J. 020, 210
Diaz, A. F. 020, 130
Di Battista, F. 030, 040
Dibrell, A. G. 020, 620
Dick, G. W. 020, 210
Dick, T. J. O. 040, 430
Dieffenbach, B. C. 020, 210
Dietrich, K. 000, 100
Diewert, W. E. 020, 200
Difiglio, C. 000, 940
Dillard, D. 030, 040
Dillard, L. G. 040, 010
Di Matteo, M. 020, 130
Dixon, H. M. 050, 030
Dosne, D. P. 040, 210
Dobriansky, L. E. 050, 310
Dockes, P. 030, 040
Dockson, R. R. 010, 510
Dohan, M. R. 050, 720
Dolan, E. G. 010, 610
Dolbear, F. T. 020, 130
Domar, E. D. 050, 110
Donkor, A. A. 020, 110
Donnelly, P. F. 020, 520
Dooley, P. C. 030, 020
Dopfer, K. 030, 110
Dore, M. H. 050, 110
Dorfman, J. 030, 040
Dorfman, R. 020, 720
Dorsett, R. A. 060, 850
Dougherty, C. R. S. 020, 800
Douglas, E. J. 020, 610
Douglas, R. C. 040, 120
Dowell, R. S. 020, 610
Drabicki, J. Z. 020, 410
Draimin, C. K. 050, 020
Drane, N. T. 010, 030
Drewnowski, J. 020, 110
Dreze, J. H. 020, 210
Dubin, J. A. 020, 210
Du Boff, R. B. 040, 620
Dubois, M. A. 050, 400
Dudko, S. J. 010
Duffy, J. A., Jr 020, 220
Dufourmaud, C. M. 010, 420
Duggan, W. A. 050, 400
Dugger, W. M. 030, 300
Duke, C. C. 020
Duman, B. L. 020, 050
Dumont, D. A. 010, 810
Dunbar, A. E. 020, 210
Duncan, A. H. 060, 020
Dung, T. H. 020, 410
Dupre, R. 040
Dvorak, E. J. 010, 310
Dye, R. A. 020
Dziadosz, T. A. 010, 310
Eadington, W. R. 020, 900
Earle, M. M. 050, 420
Easley, D. 020, 210
Easterlin, R. A. 040, 840
Eastin, R. V. 010, 320
Easton, S. T. 040, 410
Eatherly, B. J. 020, 210
Eaton, J. W. 040, 030
Eaves, G. G. 020, 510
Ebenfield, H. 000, 600
Ebert, R. R. 020, 400
Echevarria, S. O. A. 050, 520
Economides, N. S. 020, 610
Edelson, N. M. 010, 320
Edelstein, M. 040, 210
Edgmand, M. R. 020, 210
Edgren, J. A. 010, 720
Edwards, B. K. 000, 800
Egan, F. J. 020, 720
Eggleston, B. D. 020, 310
Eichengreen, B. J. 040, 400
Eichner, A. S. 020, 600
Eide, E. 020, 910
Eilenstine, D. L. 040, 120
Eisen, R. 020, 110
Elsner, R. 020, 130
Ekwurzel, D. N. 010
Ekdor, D. 010, 620
Elek, P. S. 020, 120
Eller, C. A. 020, 110
Ellerman, D. P. 020, 050
Ellickson, B. C. 020, 930
Elliott, J. E. 050, 020
Elliott, R. S. 000, 800
Ellis, D. F. 020, 210
Ellis, I. T. 010, 130
Elmore, E. A. 010, 820
Eltis, W. A. 030, 110
Eman-Zada, F. 020, 030
Emerson, H. N. 010, 320
Emmer, R. E. 030, 300
Emmons, D. W. 020
Empey, P. H. 000, 200
Endres, A. 020, 320
Engerman, S. L. 040, 840
Engers, M. 020, 210
Englander, E. 040, 620
Enos, J. L. 020, 110
Entriken, R. K. 060, 510
Erickson, D. H. 020, 840
Ericson, R. E. 020, 110
Erion, L. A. 010, 520
Esser, H. A. 020, 030
Esteve, A. 020, 030
Estrin, S. 050, 020
Eussery, J. 010, 520
Evans, K. D. 030, 310
Evans, M. 010, 720
Everding, T. C. 020, 310
Ewert, N. J. 020, 110
Eysenbach, M. L. 010, 040
Faber, M. 020
Fabian, R. G. 020, 030
Faccarello, G. J. 020, 030
Fackler, J. S. 020, 310
Fackler, W. D. 010, 310
Fagal, F. F. 000, 800
Fagan, T. W. 060, 810
Fairclotb, J. B., III 010, 050
Faith, R. L. 020, 320
Falana, O. 010
Falk, K. L. 000, 040
Falk, L. H. 010, 720
Falkinger, J. 020, 600
Fallenbuchl, Z. M. 050, 110
Fama, E. F. 010, 520
Famulla, R. M. 010, 110
Fan, C. 020, 320
Fan, L. 020, 310
Fanning, C. M. 050, 210
Farber, S. C. 020, 600
Farid, M. A. 000, 050
Farr, G. N. 040, 820
Farrar, F. A. 010, 110
Farrell, J. V. R. 020, 610
Faulhaber, R. W. 020, 610
Faulkender, R. E. 030, 040
Fautaux, J. 060, 110
Faveresu, O. 020, 720
Feeny, D. 040, 100
Fehl, U. 020, 110
Fehwel, G. R. 020, 100
Felder, J. 010, 120
Feldman, A. M. 020, 000
Feldman, R. 020, 050
Feldman, R. 010, 810
Fellner, W. J. 010, 300
Fels, R. 060, 130
Feltenstein, A. 020, 050
Felton, M. V. 020, 630
Fender, A. H. 020, 040
Feraco, M. T. 010, 630
Ferber, M. A. 050, 820
Ferleger, L. A. 040, 200
Fernandez, A. 020, 840
Ferris, S. 020, 310
Fetter, F. W. 030, 120
Field, A. J. 040, 030
Figgins, B. G. 020, 800
Fillmon, R. 020, 320
Filippini, C. 020, 620
Filppu, K. 020, 320
Finn, D. R. 030, 020
Finn, T. J. 020, 310
Finster, R. D. 020, 310
Fischbaum, M. N. 040, 020
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Fishback, P. V. 040, 820
Fishbaugh, C. P. 060, 040
Fisher, A. N. P. 020, 720
Fisher, F. M. 020, 610
Fisher, G. H. 010, 210
Fisher, M. E. 020, 310
Fishman, B. 020, 510
Fit, J. P. J. 000, 900
Fitoussi, J. S. 020, 130
Fitzherris, J. C. 040, 120
Fixler, D. J. 020, 620
Flanders, D. P. 020, 030
Flanders, J. A. 040, 430
Flaschel, P. 020, 270
Fletcher, L. B. 020, 110
Flexner, E. L. 000
Flubacher, J. F. 010, 050
Fluet, C. D. 020, 210
Foged, L. E. 010, 830
Fogel, R. W. 040, 840
Foley, D. K. 020, 310
Folkerts-Landau, D. F. I. 020, 210
Folland, S. 020, 910
Folsom, R. N. 020, 300
Fon, V. 020
Ford, L. G. 020, 830
Forensan, J. B. 020, 850
Forgang, W. 020, 310
Forrester, J. W. 050, 130
Forsund, F. R. 020, 210
Foshee, A. W. 030, 040
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Foster, J. E. 020, 320
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Francis, G. E. 030, 320
Frank, J. 020, 030
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Franke, S. F. 050, 300
Franklin, R. S. 010, 020
Fraser, H. W. 060, 910
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Freedman, R. 050, 930
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Freris, A. F. 050, 020
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Freudenthal, E. G. 010, 040
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Friedrich, J. M. 020, 320
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Fronistas, A. C. 050, 610
Froyen, R. T. 020, 310
Fudenberg, D. D. 020, 610
Fukushima, T. 020, 410
Fullenbaum, R. F. 020, 720
Funck, R. H. 010, 940
Fundaburk, E. L. 030, 050
Furbey, W. 010, 110
Furubotn, E. G. 020, 050
Fusfeld, D. R. 010, 020
Futia, C. A. 020, 310
Gaefgen, G. F. M. 020, 030
Gaffney, M. M. 010, 720
Gajewski, G. R. 040, 300
Galambos, L. 040, 610
Galatin, M. 020, 210
Galbraith, J. K. 010, 020
Gallick, E. C. 020, 610
Gallman, R. E. 040, 000
Gallo, J. C. 060, 610
Gamber, E. N. 010, 220
Gammon, J. 010, 210
Ganguly, P. 020, 710
Garb, G. 020, 850
Garbacz, S. L. 010, 210
Garbero, P. 010, 130
Garcia, Z. 010, 310
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Gardner, R. J. 020, 050
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Gassler, R. S. 020, 320
Gaudet, G. O. 020, 720
Gaunitz, S. 040, 610
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Geerling, D. G. 020, 820
Geipel, U. 020, 210
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Gelfand, J. E. 020, 310
Gelman, J. R. 020, 610
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George, D. L. 020, 910
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George, R. E. 020, 050
Georgescu-Roegen, N. 020, 720
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Gherity, J. A. 030, 020
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Ghosh, R. N. 020, 030
Giacalone, J. A. 010, 040
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Giannetti, R. 030, 040
Gibbons, J. M. 010, 710
Gibbons, R. J. 040, 420
Giesbrecht, M. G. 010, 030
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Gilbert, G. N. 040, 030
Gilbert, H. A. 020, 710
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Ginsberg, W. 020, 210
Gisbert, J. 050, 120
Gisser, M. 020, 720
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Goldstein, J. P. 020, 210
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Gonce, R. A. 030, 610
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Goodfriend, M. J. 000, 210
Goodstein, M. E. 010, 910
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Gordon, H. S. 030, 020
Gordon, K. S. 030, 020
Gorga, C. 020, 110
Gorlin, A. C. 050, 630
Gorman, W. M. 010, 920
Goss, B. A. 010, 030
Gott, E. M. 000, 900
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Gould, J. P. 020, 210
Gould, M. 020, 040
Gouveia, T. 020, 130
Gowens, P. R. 020, 210
Grabowe, R. F. 000, 600
Grady, J. S. 010, 320
Graeser, P. 020, 610
Graham, D. A. 020
Graham, J. W. 020, 850
Gramlich, E. M. 010, 320
Grampp, W. D. 020, 030
Grant, P. B. 040
Grey, D. A. 010, 020
Gray, K. R. 050, 320
Gray, R. 040, 320
Gray, S. H. 020, 800
Graziani, A. 010, 030
Graziola, G. 020, 110
Greaves, B. B. 020, 060
Greaves, P. L., Jr 020, 310
Green, D. W. 050, 110
Green, G. D. 040
Green, H. A. 010, 320
Green, J. 020, 410
Greenfield, H. I. 010, 800
Greenhut, M. L. 020, 940
Greenslade, G. S. 050, 110
Gregoire, P. 020, 030
Gregory, P. R. 050, 840
Greta, R. L. 010, 500
Groenewegen, P. D. 030, 320
Grohs, R. J. 010, 110
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Grossman, S. J. 020, 520
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Gruchy, A. G., Sr 030, 050
Grunberg, E. 020, 030
Gubins, S. 020, 930
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Guerin, J. R. 020, 320
Gunderson, G. 040, 110

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Gunning, J. W. 020, 110
Gunter, F. R. 020, 100
Gupta, S. 020, 210
Gupta, S. P. 020, 210
Gurley, J. G. 050, 310
Gurzynski, Z. S. A. 020, 930
Gustafson, J. W. 020, 320
Guthrie, W. G. 030, 020
Guyton, P. L. 060, 050
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Haber, L. J. 020, 520
Habib, M. A. 020, 200
Hadar, J. 020, 210
Hagemann, H. 020, 110
Hagerling, S. W. 050
Haines, M. R. 040, 840
Haites, E. F. 040, 930
Haldi, J. 010, 320
Haley, B. F. 020, 030
Hall, W. 050, 420
Haller, G. 020, 400
Haller, W. 040, 610
Halsey, H. I. 010, 210
Halthwanger, J. C., Jr 010, 820
Halvorsen, M. L. 020, 610
Hamalainen, A. 030, 010
Hamilton, E. J. 040, 310
Hamilton, R. 020, 540
Hammond, P. J. 020, 110
Han, G. S. 020, 310
Hancock, J. L. 040, 310
Handa, J. C. 020, 310
Handa, D. W. 020, 030
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Hanis, E. H. 050, 210
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Hanson, G. 010, 020
Hanson, J. R., II 040, 120
Harcourt, G. C. 020, 030
Harder, F. L. 020, 310
Hardt, J. P. 050, 420
Hare, P. G. 020, 110
Harel, G. I. 020, 820
Harger, B. T. 010, 020
Harley, C. K. 040, 100
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Harris, J. D. 050, 510
Harris, M. 020, 210
Harris, R. G. 020, 210
Harris, S. E. 020, 110
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Hartmann, H. I. 040, 820
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Hartwig, K. 020, 050
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Harvey, C. E. 050, 720
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Hashimoto, H. 020, 720
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Haslinger, F. H. 020, 300
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Hayes, J. A. 020, 210
Hayes, R. E. 040, 820
Hayes, W. A. 020, 410
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Haynes, L. 010, 400
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Head, E. P. 000
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Heiburn, S. W. 060, 810
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Heller, W. P. 020, 110
Heller, W. W. 010, 320
Helmstadter, E. 020, 110
Hemond, R. L. 010, 320
Hemphill, R. C. 010
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Herberg, H. 020, 410
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Herren, R. S. 040, 610
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Heyne, P. T. 010, 030
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Higgins, P. G. 020, 000
Higgins, R. S. 020, 610
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High, S. H. 020, 220
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Hill, L. E. 030, 040
Hill, R. L. 010, 300
Hillendahl, W. H. 010, 300
Hillinger, C. 020, 210
Hinckley, R. 000, 600
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Hines, A. G. 020, 130
Hirsch, A. 030, 000
Hirsch, E. 030, 000
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Hise, K. W. 020, 060
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Hoath, J. R. 010, 110
Hocevar, J. 030, 050
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Holderness, C. G. 010, 610
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Hollander, H. 020, 130
Hollander, S. 030, 020
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Holmes, J. T. 020, 720
Holmes, W. L. 020, 210
Holt, C. A. 020, 610
Holthausen, D. M. 020, 610
Holub, H. W. 010, 200
Honkaleinto, O. 020, 210
Honkapohja, S. M. S. 020, 210
Hool, R. B. 020, 310
Hope, B. F. 030, 110
Hopkins, R. J. 010, 710
Horlacher, D. E. 010, 110
Horney, M. J. 020, 210
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Horowitz, I. 020, 610
Horwich, G. 020, 310
Hosomatsu, Y. 020, 210
Hotson, J. H. 020, 300
Houmann, O. B. 020, 320
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Howey, R. S. 030, 020
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Huberman, G. 020, 310
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Ilmakunnas, P. J. A. 020
Imai, H. 020
Inaba, F. S. 020, 210
Ingram, J. W. 020, 000
Intriligator, M. D. 020, 210
Inwood, E. L. 010, 030
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Isaac, R. M. 020, 610
Israelsen, L. D. 050, 040
Issawi, C. 040, 110
Ito, T. 020, 110
Iwand, T. 020, 030
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Jackson, F. H. 010, 020
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James, H. W. 010, 020
James, J. A. 040, 610
Janeway, W. H. 030, 300
Janssen, M. C. 010
Jeanfreau, A. J., III 020, 520
Jeffress, P. W. 010, 220
Jenninga, F. B., Jr 000, 600
Jenninga, R. M. 040, 540
Jensen, C. E. 020, 000
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Johnston, R. S. 020, 710
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Kasun, J. R. 050, 110
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Kelly, R. W. 020, 720
Kelly, W. A., Jr 020, 520
Kelly, W. J. 050, 840
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Kennan, J. F. 020, 820
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Kennedy, M. P. 020, 400
Kennedy, T. E. 020, 600
Kennedy, W. P. 040, 620
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Kibreab, C. 020, 030
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Kihl, K. 020, 920
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Kilpatrick, J. A. 050, 120
Kim, H. K. 020, 410
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Kings, J. B. 010
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Klant, J. J. 030, 310
Klapholz, K. 010, 000
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Kleinhueckelskot, D. H. 020, 800
Kleinman, S. D. 010, 810
Klevorick, A. K. 020, 610
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Klinkmuller, E. 050, 040
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Klonsky, H. 040, 310
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Knecht, R. 020, 820
Knopf, K. A. 010, 830
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Kochevar, C. H. 010, 520
Koenig, E. F. 020, 130
Koetter, R. 020, 030
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Kogiku, K. C. 020, 210
Kohler, H. 050, 400
Kohut, J. M. 010, 610
Koizumi, T. 020, 410
Kolatch, B. S. 020, 610
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Kormendi, R. C. 020, 300
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Lawler, N. E. 020, 120
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Pincus, J. J. 040, 420
Pinsky, G. A. 010, 220
Piron, R. 020, 030
Pix, M. 030, 040
Pizzigno, G. D. 020, 200
Plantz, D. V. 020, 030
Plotkin, N. 010, 300
Plott, C. R. 020, 610
Plummer, M. L. 020, 720
Plummer, N. K. 010, 030
Podar, M. K. 010, 610
Politte, R. Z. 010
Polkinghorn, B. H. 030, 020
Pollak, R. A. 020, 220
Pope, C. 040, 000
Porstmann, R. 020, 030
Porta, P. L. 020, 030
Porter, D. A. 010, 020
Porter, E. D. 020, 720
Porter, P. K. 020, 210
Porter, W. R. 020, 600
Posner, R. A. 000, 610
Postlewaite, A. W. 020
Potok, L. A. 020, 820
Poulon, F. 020, 300
Poulson, B. W. 040, 120
Pourian, H. 020, 310
Pournarakis, M. D. 000, 400
Powell, B. E. 020, 610
Powell, J. W. 010, 700
Power, J. H. 020, 110
Powers, J. A. 020, 210
Prendergast, G. A. 020, 040
Prescott, E. C. 020, 000
Pressman, S. 030, 020
Price, J. E. 020, 130
Prijono, T. 010, 850
Prisching, M. 010, 030
Proschansky, H. 040, 820
Prunella, P. J. 010, 630
Prychitko, D. L. 020
Pryor, F. L. 050, 110
Pryor, L. S. 040, 010
Pulsinelli, R. W. 010, 020
Purdum, J. J. J. 040, 020
Puth, R. C. 040, 020
Putterman, L. G. 050, 120
Pyron, T. W. 020, 410
Quintas, J. R. 020, 940
Radner, R. 020, 210
Radwick, O. 020, 110
Rahmeyer, F. 020, 130
Ram-Mohan, S. 020, 210
Ramon, S. M. 010, 120
Ramstad, Y. 030, 800
Ranck, E. L. 020, 320
Randall, L. R. 040, 120
Ransom, R. L. 040, 010
Rao, N. K. 020, 110
Rapczak, J. J. 020, 210
Rapp, K. L. 010, 130
Rashid, S. 020, 030
Rasmusen, E. B. 020, 210
Rasmussen, D. A. 020, 300
Rasmussen, P. N. 020, 320
Ratliff, C. E., Jr 010, 320
Ratner, S. 040, 610
Ray, C. G. 040, 310
Ray, G. 010, 500
Raymon, N. 020, 210
Rea, K. J. 040, 120
Rea, T. A. 010
Reagan, E. P. 020, 610
Reddall, R. G. 060, 520
Reekie, C. I. M. 020, 520
Reetz, N. 020, 410
Reid, G. C. 020, 610
Reid, J. D., Jr 040, 830
Reid, P. A. 010, 210
Reilly, R. J. 020, 210
Reilly-Petrone, M. M. 010, 430
Reinganum, J. F. 020, 620
Reinhardt, P. G. 020, 210
Reinhart, B. 010, 030
Reinwald, T. P. 020, 030
Reisman, G. G. 020, 050
Remington, L. J. 010, 320
Rendich, M. F. 020, 310
Renning, H. D. 050, 030
Renshaw, R. H. 030, 020
Repullo Labrador, R. 020, 210
Reque, R. B. 010, 110
Reuten, G. A. 030, 110
Reynolds, B. L. 050, 100
Reynolds, R. S. 010, 210
Reynolds, W. M. 010, 310
Reza, A. M. 020, 310

Reznik, N. D. 010, 050
Rezny, R. R. 010, 920
Rhee, H. Y. 020, 410
Rhodes, J. 020, 130
Richards, V. A. 050, 110
Richter, D. K. 020, 320
Richter, R. 020, 310
Rider, C. 020, 120
Ridley, A. N. 010, 020
Riley, J. G. 020
Rimlinger, G. V. 040, 120
Riordan, M. H. 020, 600
Rios, R. J. 010, 800
Ripoll, A. B. 030, 020
Rittenhouse, B. E. 030, 930
Rivas, J. M. 020, 810
Rizzo, S. G. 030, 430
Roberts, B. 010, 210
Roberts, C. C. 010, 220
Roberts, D. C. 020, 310
Roberts, D. J. 020, 610
Roberts, N. 010, 210
Robertsen, K. 020, 110
Robertson, J. K. 020, 210
Robinson, D. E. 020, 040
Robinson, N. Y. 010, 310
Robinson, R. 020, 610
Robinson, W. D. 020, 300
Rock, C. P. 050, 120
Rock, J. A. T. 020, 060
Rockoff, H. T. 040, 310
Rockwood, C. E. 020, 610
Roddy, V. E. 000, 100
Rodgers, J. D. 020, 320
Rodrigues, A. P. 020, 210
Rodriguez, T. M. 010, 710
Rodriguez-Pastor, J. M. 020, 110
Roehl, R. W. 040, 010
Roemer, J. E. 020, 440
Rogstad, B. 010, 120
Rohwedder, J. 020, 400
Rolfe, C. J. 020, 520
Roman, D. K. 040, 050
Roman, P. D. 020, 210
Romano, R. M. 030, 600
Romig, R. P. 010, 830
Rooney, R. F. 020, 720
Ropke, J. 020, 110
Rose, B. J., III 010, 720
Rose, G. G. 020, 610
Rosefields, S. 050, 410
Rosenberg, N. 040, 620
Rosenkranz, E. C. 020, 210
Rosovsky, H. 040, 120
Ross, L. L. 010, 810
Ross, R. P. 010, 310
Rosse, J. N. 020, 210
Rossini, G. 010, 600
Rossman, J. C. 000, 400
Rotella, E. J. 040, 810
Roth, J. D. 010, 810
Roth, T. P. 020, 610
Rothschild, K. W. 020, 820
Rothschild, M. 020, 600
Rothschild, R. 020
Rothwell, J. C. 000, 040
Rottenberg, S. 010, 800
Roughgarden, J. D. 020, 030
Roumasset, J. A. 020, 110
Rountree, N. C. 020, 310
Rousseaux, P. P. 010, 030
Rowcroft, J. E. 020, 920
Rowe, B. 010, 920
Rowe, J. W. 020
Rowland, T. L. 040, 030
Rubin, P. H. 020, 610
Rugg, D. D. 020, 520
Ruhter, W. E. 020, 610
Ruiz-Castillo, J. 020, 900
Ruiz-Oliveras, W. 020, 910
Rupert, P. P. M. 010
Ruppert, R. W. 020, 720
Russell, J. J. 010, 800
Russell, M. B. 000, A00
Rutherford, M. H. 030, 720
Rutner, J. L. 010, 210
Ruud, T. 020, 900
Ruys, P. H. M. 000, 210
Ryan, R. M. 040
Rynning, J. L. 040, 210
Saba, R. P. 020, 600
Saether, A. 020, 940
Sah, R. 020, 320
Sakai, Y. 020, 210
Sakellariou, D. M. 020, 210
Salant, D. 020
Salazar-Carrillo, J. 010, 110
Salkever, L. R. 030, 820
Salkin, J. S. 020, 320
Salles, M. 020, 210
Samuels, W. J. 030, 320
Samuelson, L. 020
Samuelson, P. A. 020, 210
Samuelson, W. F. 020, 410
Sanborn, H. N. 010, 300
Sandelin, B. A. N. 030, 930
Sandler, T. 020, 320
Sandmo, A. 020, 320
Sanfuentes, A. 020, 800
Sang, H. K. 020, 110
Sapozhnik, R. 020, 210
Sarantides, R. P. 020, 430
Sarayder, E. 040, 830
Sard, E. L. 020, 130
Sardella, C. 020
Sarin, R. K. 050, 210
Sarkar, S. 020
Sarndal, A. G. 020, 310
Sato, F. 020, 010
Sato, K. 020, 110
Sato, R. 020, 210
Satterthwaite, M. A. 020, 910
Sattinger, M. 020, 800
Saunders, G. K. 000, 130
Saunders, P. 060, 830
Saunders, P. J. 010, 310
Sauter, J. V. 010, 300
Sav, G. T. 020, 210
Sawyer, W. C. 020, 420
Scarbrough, J. E. 020, 630
Scarf, H. 020
Schankow, G. 020, 430
Scheele, E. 020, 110
Scheffman, D. T. 020, 610
Schefold, B. 020, 030
Scheibert-Syfrig, H. 020, 210
Schenk, K. E. 050, 420
Schepe, H. B. 010, 210
Scherage, J. D. 020, 620
Schick, G. A. 020, 310
Schiming, R. C. 010, 310
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Schmid, A. A. 050, 720
Schmidt, G. J. 040, 310
Schmidt, W. R. 000, 300
Schnabl, H. 020, 920
Schneider, W. 010, 720
Schoene, S. W. 040, 020
Schoenholtz, K. L. 000, 400
Schoofs, P. J. 020, 030
Schooler, E. W. 020, 610
Schor, J. B. 020, 820
Schott, F. H. 010, 300
Schotter, A. 020, 320
Schramm, J. C. 030, 060
Schreffler, D. K. 010, 020
Schreiber, W. L. 010, 320
Schrock, N. W. 020, 310
Schroeder, E. A. 020, 200
Schultz, D. A. 020, 130
Schultz, T. F. 010, 320
Schumann, J. 010, 210
Schupbach, R. L. 030, 850
Schwartz, P. 030, 610
Schwartz, R. A. 020, 520
Schwarz, G. E. 000, 800
Schweitzer, A. 050, 030
Schwier, A. S. 020, 030
Schwoediauer, G. 020, 130
Scitovsky, T. 020, 130
Scotchmer, S. A. 020, 210
Scott, D. T. 030, 020
Scott, E. H. 010, 050
Scoufelis, A. 000, 040
Seaman, B. A. 020, 610
Seater, J. J. 020, 130
Sebestyen, Z. H. 020, 410
Sechzer, S. L. 020, 210
See, H. F. 020, 320
Segal, H. H. 030, 310
Seidenfus, H. S. 010, 610
Seidl, C. 020, 320
Seidler, G. 030, 610
Seiden, L. 020, 520
Seidon, J. R. 020, 910
Sen, A. K. 020, 110
Senn, P. R. 030, 010
Serra-Puche, J. 020, 320
Sesnowitz, M. L. 010, 320
Shafer, J. W. 020, 210
Shahan, E. P. 050, 030
Shalit, H. 020, 720
Shammas, C. 040, 920
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Shapiro, C. 020, 600
Shapiro, D. L. 020, 720
Shapiro, S. L. 040, 020
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Sharpe, M. E. 010, 110
Sharshar, A. M. 050, 110
Shavell, S. 020, 210
Shaw, J. A. 040, 020
Shawki, A. M. A. 020, 050
Sheakley, W. H. 000, 310
Shefrin, H. M. 020, 920
Sheldon, G. G. 040, 610
Shell, K. 020, 300
Shepherd, A. R. 020, 410
Shepherd, G. S. 010, 710
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Sherman, H. J. 050, 130
Sherman, S. Z. 030, A00
Shima, E. 020, 120
Shingleton, V. 010, 830
Shipe, M. A. 030, 600
Shirven, M. N., II 040, 620
Shishko, R. 020, 810
Shlomowitz, R. 040
Shoukry, K. 020, 400
Shrager, S. A. 020, 210
Shubik, M. 020, 030
Sicilian, J. M. 020, 210
Siebert, C. D. 010, 100
Sievers, A. M. 030, 120
Siguenza, M. 010, 110
Siljen, J. J. 020, 430
Silberberg, E. 010, 020
Sillers, D. A. 020, 710
Silver, M. 020, 820
Simon, H. A. 020, 510
Simon, L. K. 020
Simon, M. J. 020, 910
Simos, E. O. 020, 110
Singh, N. 020, 210
Singh, V. N. 020, 110
Sioshansi, F. P. 050, 110
Sjoblom, K. A. 020, 620
Skeels, J. G. 020, 310
Skeels, J. W. 050, 800
Skinner, J. W. 020, 610
Skouras, A. 020, 030
Skov, I. L. 050, 060
Skurski, R. B. 050, 630
Slate, D. M. 020, 510
Slater, M. D. E. 020, 600
Slivinski, A. D. 020, 410
Sloan, V. B. 020, 830
Smeaton, D. 000, 200
Smiley, W. G. 040, 010
Smith, B. A. 050, 930
Smith, C. I. 020, 310
Smith, G. R. 020, 120
Smith, H. M. 010, 400
Smith, H. W. 010, 940
Smith, J. F. 010
Smith, K. H. 000, 400
Smith, K. R. 020, 810
Smith, L. G. 050, 850
Smith, N. S. 020, 110
Smith, R. D. 020, 820
Smith, R. E. 010, 430
Smith, V. L. 020, 210
Smith, W. R. 010, 530
Smolinski, L. 050, 110
Smyth, D. J. 020, 300
Snavely, W. P. 050, 110
Snead, K. 040, 810
Snead, W. G. 050, 400
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Snyder, J. H. 010, 820
Snyder, T. K. 010, 630
Sobel, I. 030, 800
Soh, B. H. 020, 130
Sokoloff, K. 040, 310
Solomon, L. K. 020, 220
Solomon, M. B. 050, 510
Solow, R. M. 020, 100
Soltow, L. C. 040, 220
Sonnenschein, H. 020, 210
Sonstegaard, M. H. 020, 610
Sontheimer, K. C. 020, 610
Soofi, A. S. 030, 130
Soper, J. C. 060, 040
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Sosin, K. 020, 620
Soudek, J. 030, 420
Sousa Andrade, J. A. 020, 310
Southworth, B. W. 010, 520
Sowell, T. 030, 820
Spaeling, D. 020, 820
Spatt, C. S. 020, 610
Spechler, M. C. 050, 040
Spence, A. M. 020, 610
Spencer, A. H. 040, 610
Spengler, J. J. 030, 840
Spichiger, J. R. 050, 030
Spiegel, H. W. 030, 020
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Spivak, A. 020, 310
Spooner, F. C. 040, 100
Sprague, G. A. 050, 520
Spreng, F. 030, 510
Spulber, D. F. 020, 720
Stafford, F. P. 010, 820
Stahl, D. O., II 020, 310
Stahl, K. O. 020, 930
Staiger, D. S. 010, 520
Staller, G. J. 050, 110
Staples, G. H. 030, 060
Starobin, H. 050, 430
Starr, P. C. 050, 110
Starrett, D. A. 020, 320
St Clair, D. J. 040, 030
Steckel, R. H. 040, 840
Steele, K. R. 000, 500
Stein, J. L. 020, 310
Steinberg, I. S. 020, 520
Steiner, J. E. 050, 120
Steiner, P. O. 020, 610
Steinmeier, T. L. 020, 210
Stephens, J. K. 020, 110
Stephenson, M. A. 020, 030
Stern, L. A. W. 020, 810
Stettler, H. L. 040
Stevens, D. 030, 310
Stevens, D. N. 020, 030
Stevens, J. N. 050, 400
Stewart, M. B. 020, 720
Stigler, G. J. 020, 600
Stiglitz, J. E. 020, 620
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Stober, W. J. 020, 000
Stockfisch, J. A. 020, 320
Stokey, N. L. 020, 610
Stollman, R. 020, 930
Stone, C. C. 020, 310
Stone, I. 040, 440
Stout, R. A. 020, 210
St Pierre, G. J. 010, 020
Strazicich, M. C. 020, 210
Streeter, L. E. 020, 210
Stribling, H. A., Jr 030, 520
Strom, R. J. 060, 310
Struckmeyer, C. S. 020, 430
Stuart, C. E. 020, 900
Stuart, R. C. 050, 110
Sturgeon, R. R. 020, 520
Sturgis, M. R. 020, 800
Sturm, R. W. 050, 120
Suarez, A. S. 010, 520
Sullivan, T. E. 040, 320
Sumberg, A. D. 040, 830
Sun, L. 030, 320
Sunday, A. A. 010, 050
Sundquist, B. J. 010, 400
Supel, T. M. 020, 310
Suranyi-Unger, T., Jr 010, 920
Sutch, R. C. 040, 310
Sutton, T. P. 020, 940
Suwanakul, S. 020, 110
Suzawa, G. S. 020, 110
Suzumura, K. 020
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Swanstrom, R. T. 040, 060
Sweeney, G. H. 020, 610
Sweeney, J. L. 020, 720
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Sykes, D. 020, 210
Sylla, R. E. 040, 310
Szumilo, F. A. 050, 110
Taga, L. S. 050, 610
Takayama, A. 020, 410
Takede, S. 020, 110
Talley, W. K. 020, 610
Talmers, W. N. 020, 410
Tanaka, F. J. 050
Tarpinan, G. 000, 100
Tarr, D. G. 020, 420
Taub, A. J. 020, 210
Taylor, G. R. 040, 120
Taylor, K. S. 040, 120
Taylor, N. W. 040, 120
Taylor, W. R. 020, 720
Teichert, P. C. M. 010, 120
Teixeira Ribeiro, J. J. 010, 320
Temin, P. 040, 910
Temple, F. C. 010, 020
Templer, R. L. 060, 020
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Terrell, W. T. 020, 210
Thatcher, J. G. 020, 520
Theige, G. L. 010, 110
Theophanides, S. M. 010, 520
Theroux, D. J. 020, 610
Thiel, S. E. 020, 600
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Thomas, E. 010, 000
Thomas, R. L. 010, 310
Thomas, R. W. 010, 720
Thomopoulos, P. A. 010, 600
Thompson, A. A. 020, 610
Thompson, E. A. 000, 300
Thompson, H. G., Jr 060, 820
Thompson, J. F. 010, 510
Thompson, J. H. 030, 050
Thomson, D. L. 030, 020
Thomson, H. F. 030, 310
Thomson, W. L. 020
Thornhill, J. N. 020, 830
Thornton, B. T. 010, 530
Thornton, J. R. 050, 020
Threen, C. S. 020, 210
Thrasher, M. S. 020, 800
Thweatt, W. O. 030, 010
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Tietz, R. 020, 210
Timmis, G. C. 020, 210
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Tipton, G. B. 020, 030
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Tjin Wong Joe, R. A. 020, 320
Tobin, J. 020, 300
Toda, Y. 050, 210
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Todt, H. 020, 940
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Tolley, G. S. 010, 930
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Tomaske, J. A. 040, 840
Tomono, N. 010, 020
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Tool, M. R. 030, 050
Torres, A. 020, 820
Toruno, M. C. 030, 050
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Tourinho, O. A. F. 020, 210
Townsend, K. N. 030, 720
Townsend, P. A. 040
Townsend, R. G. 010, 610
Trajtenberg, M. 020, 620
Traore, A. D. 020, 210
Treires, J. J. 050, 130
Tremi, V. G. 050, 210
Tressler, J. H. 020, 410
Trethewey, R. J. 040, 020
Triantafillou, P. 010, 210
Tribble, J. A. 060, 400
Troullinos, M. 020
Truett, D. 020, 120
Truett, L. F. 020, 520
Trultt, W. J. 020, 210
Tsang, H. H. 020, 210
Tuchscherer, T. 020, 310
Tuchtfeldt, E. 050, 610
Tuck, L. S. 020, 210
Tullock, G. 000, 010
Tuma, E. H. 040, 120
Turban, M. 050, 100
Turek-Brexins, J. L. 020, 210
Turnovsky, S. J. 020, 210
Turpin, W. N. 010, 400
Tuttle, F. W. 040, 310
Tyran, B. 010, 520
Tyson, L. D. 050, 110
Uhlmchuk, G. A. 010, 320
Uhr, C. G. 030, 020
Ullrich, F. J. 030, 020
Ulmer, R. L. 060, 310
Ulveling, E. F. 010, 210
Umeda, M. 020, 030
Umentum, P. P. 010
Upton, C. W. 020, 930
Urbantke, H. E. 040, 530
Urso, R. L. 020, 610
Usem, H. S. 020, 610
Uselding, P. J. 040, 620
Usher, D. 020, 220
Uzoaru, B. O. 020, 510
Valtheswaran, J. 030
Valtheswaran, R. 030, 020
Vallegeas, B. 020, 310
Valli, V. 050, 110
Valverde, P. J. 020, 040
Van Atta, S. 020, 310
Van Broekhoven, E. J. J. 010, 920
Van Cott, T. N. 020, 320
Van Daal, J. 020, 210
Vandegrift, S. R. 010, 210
Vandenbosch, F. 020, 220
Van Den Doel, H. 050, 320
Van Den Haag, E. 010, 020
Vandermeulen, D. C. 020, 110
Van Der Veen, R. F. 030, 620
Van Der Weijden, C. J. 020, 100
Vandoorne, M. 020, 030
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Vann, B. L. 020, 620
Van Noorden, R. J. 020, 200
Vanorder, R. A. 010, 310
Van Santen, F. 020, 010
Varian, H. R. 020, 210
Varri, P. P. 010, 210
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Vaughn, K. I. 030, 020
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Veenbergen, J. G. 020, 100
Verdon, W. A. 060, 850
Vermeet, A. J. 020, 030
Vibe Pedersen, J. 010, 400
Vickers, D. 020, 030
Villaronga, L. M. 060, 030
Villavicencio, R. A. 010, 220
Vind, K. 020, 210
Vining, R. 020, 210
Virkler, J. S. 010, 040
Virmani, A. 020, 300
Vogl, G. 020
Vogt, W. 020, 110
Voltaire, K. 020, 210
Von Knorring, E. 020, 630
Von Luede, R. 060, 920
Von Weizsacker, C. C. 020, 600
Vorhies, W. F. 020, 320

Voegerau, H. 020, 400
Vowels, R. C. 010, 220
Voyatzis, J. G. 020, 410
Vredeveld, G. M. 060, 820
Vroman, S. 020, 820
Waddell, J. A. 010, 830
Wagner, H. 000, 100
Wagner, J. L. 000, 940
Wagner, R. E. 020, 320
Wagner, W. C. 030, 010
Wahed, J. A. 010, 000
Wakasugi, R. 020, 610
Walker, D. A. 020, 030
Walker, J. 010, 610
Walsh, D. K. 020, 110
Walstad, W. 060, 910
Walton, G. M. 040, 620
Wang, L. F. S. 020, 410
Wang, T. 050, 100
Wannamaker, A. J. M. 040, 130
Ward, R. C. 020, 040
Warner, R. M., Jr 060, 520
Warnke, D. W. 020, 310
Warren, G. E. 010, 310
Waters, W. R. 030, 040
Watkins, K. 010, 310
Watkins, M. F. 040, 840
Watson, S. C. 040, 700
Watters, F. M. 050, 040
Watts, M. W. 060, 030
Webb, R. H. 020, 130
Webb, S. B. 040, 310
Webb, S. H. 010, 710
Wechsler, B. 010, 510
Wedlund, S. G., Jr 010, 130
Weglarski, M. M. 020, 310
Wegner, E. 000, 800
Wehner, H. 010, 930
Wehrs, W. E. 020, 210
Weichsel, W. J. 050, 410
Weidenaar, D. J. 010, 850
Weinstein, J. W. 050, 210
Weinstein, M. M. 040, 310
Weintraub, E. R. 020, 030
Weintraub, I. 030, 050
Weintraub, S. 010, 130
Weir, D. R. 040, 840
Weir, K. H. 010, 610
Weiss, K. 020, 320
Weiss, R. A. 010, 200
Weiss, R. S. 040, 030
Weisskopf, T. E. 050, 120
Weisskopf, W. A. 010, 030
Weitzman, M. L. 050, 020
Welch, R. G. 010, 310
Weller, P. A. 020, 320
Welsh, A. L. 060, 010
Wemelsfelder, J. 000, 400
Wenders, J. T. 020, 610
Wenig, A. 020, 130
Wernette, J. P. 010, 130
Wertheimer, R. G. 010, 430
Wessel, R. H. 020, 060
West, E. G. 020, 030
West, R. C. 040, 310
West, S. D., Jr 010, 540
West, T. 010, 320
Westfield, F. M. 020, 600
Weston, J. L. 040, 310
Weymark, J. A. 020, 320
Whinnery, D. R. 010
Whinston, M. D. 020, 610
Whipple, D. R. 020, 910
Whitaker, J. K. 020, 030
White, E. E., III 020, A00
White, E. N. 040, 310
White, W. T. 050, 300
Whiteman, C. H. 020, 210
Whiteman, T. C. 000, 200
Whitin, T. M. 020, 210
Whitlock, E. G. 020, 320
Whitmore, H. W. 020, 300
Whitney, W. G. 040, 050
Whitten, D. O. 040, 220
Wichers, C. R. 020, 210
Wickham, C. H. 040, 110
Wickham, E. D. 020, 110
Wickstroem, B. 020, 050
Widmaier, H. P. 050, 820
Wieczorek, N. 050, 310
Wiedemann, P. P. 050, 110
Wiedemer, J. D. 040, 130
Wiener, J. L. 020, 030
Wietfeldt, H., Jr 010, 440
Wilburn, R. C. 010, 310
Wilcox, E. D. 020, 210
Wilde, L. L. 020
Wilds, M. C. 010, 210
Wilderstrom, S. H. 010, 220
Wilea, J. L. 040, 810
Wilhelm, H. M. 000, 800
Wilkins, M. 040, 440
Willett, E. J. 020, 310
Williams, A. W. 010, 020
Williams, C. 050, 430
Williams, C. S. 010, 510
Williams, E. J. 020, 600
Williams, G. G. 010, 610
Williams, L. A. 010
Williamson, E. 010, 040
Williamson, H. F. 040, 630
Williamson, J. G. 040, 100
Williamson, S. H. 040, 320
Willig, R. D. 020, 610
Willoughby, J. A. 020, 440
Wills, H. R. 020, 210
Wilson, C. A. 020, 410
Wilson, C. Z. 000, 510
Wilson, J. D. 010, 310
Wilson, J. H. 010, 530
Wilson, R. S. 020, 210
Wiltgen, R. J. 030, 050
Wimmer, L. T. 040, 020
Winckler, G. 000, 300
Winder, J. W. L. 020, 310
Windisch, R. 020, 320
Wineland, T. D. 020, 610
Winestone, R. L. 020, 320
Winkelman, R. D. 030, 040
Winnick, A. J. 020, 210
Winston, G. C. 020, 640
Winter, S. G. 020, 610
Winters, B. C. 010, 000
Wirthlin, R. B. 020, 120
Wisley, T. O. 020, 130
Withers, G. A. 010, 800
Withington, R. P., Jr 040, 830
Witzmann, U. 020, 300
Woirol, G. R. 030, 610
Wojtun, B. S. 000, 840
Wolf, C. 020, 400
Wolf, R. G. 010, 020
Wolfe, F. E. 020, 030
Wolfenbarger, J. L. 050, 110
Wolfson, M. 030, 210
Wolfson, R. J. 030, 020
Wolfstetter, E. 020, 130
Wolkowitz, B. 020, 310
Wolpe, J. A. 010, 520
Wong, C. M. 020, 120
Wood, E. W. 020, 320
Wood, J. W. 000, 720
Wooders, M. 020, 930
Woodman, L. 020, 310
Woodruff, R. J. 040, 240
Woodruff, W. 040, 400
Worcester, D. A., Jr 050, 820
Worland, S. T. 030
Wormser, F. E. 010, 310
Worseck, R. A. 010, 710
Worswick, G. D. N. 010, 130
Worthington, R. E. 010, 310
Wrean, W. H. 020, 310
Wright, G. 040, 210
Wu, S. 020, 610
Wubben, W. D. 010, 830
Wyman, P. R. 010, 040
Wynd, A. W. 010, 610
Wyans, P. L. 020, 610
Wyanyczuk, A. 020, 130
Wyzan, M. L. 050, 210
Yaari, M. E. 020
Yamamoto, K. 020
Yamanaka, T. 020, 410
Yandell, D. S. 020, 610
Yandle, B. 020, 610
Yang, C. W. 010
Yankovic, D. J. 010, 040
Yarbrough, B. V. 020, 400
Yarbrough, R. M. 020, 210
Yates, J. N. 060, 900
Yeager, J. H. 010, 130
Yeargan, H. R. 020, 320
Ying, J. T. 020, 050
Yohe, G. W. 020, 320
Yoho, D. L. 060, 810
Yoo, J. H. 020, 200
Yoon, S. 020, 030
Yoshikawa, H. 020, 130
Yoshioka, T. 020, 610
Youell, R. J. 010, 510
Young, F. 010, 600
Young, J. T. 030, 720
Young, L. Y. H. 000, 200
Youngquist, J. C. 010, 310
Yun, P. S. 020, 110
Yunker, J. A. 050, 020
Zabarkes, A. B. 020, 930
Zabel, E. 020, 050
Zaghini, E. 020, 210
Zahid, A. A. 020, 210
Zahn, F. 020, 310
Zarembe, A. L. 010, 300
Zarka, A. 020, 210
Zec, G. C. 010, 920
Zeckhauser, R. J. 020, 610
Zeman, A. H. 030, 040
Zietz, J. 010, 320
Zimmer, B. G. 020, 110
Zimmer, W. J. 040, 020
Zinam, O. 050, 030
Zincone, L. H. 020, 320
Zingler, E. K. 030, 020
Zinn, K. G. 050, 420
Znayenko, W. 050, 110
Zuidema, R. P. 020, 900

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Abed, G. T. 110, 400
Abegaz, B. 110, 810
Abramovitz, M. 110, 130
Ackley, G. 130, 300
Adams, J. 100, 400
Adams, J. A. 130, 040
Adams, W. B. 110, 210
Adelman, I. 110, 210
Adler, H. A. 110, 630
Agarwala, R. 110, 120
Agosin, M. R. 120, 130
Ahmad, E. 110, 320
Akacem, M. 110, 310
Aker, U. 110, 120
Akeoy, M. A. 110, 820
Akyeampong, K. 120, 440
Alberta, T. 120, 110
Alenier, H. S. 130, 210
Alexander, J. 110, 610
Alexander, R. J. 120, 050
Alexander, W. S. 130, 210
Ali, R. 110, 440
Allaway, W. 130, 210
Allen, K. B. 120, 220
Allon, D. J. 120
Almon, C. 130, 210
Alnasrawi, A. 120, 630
Alogoskoufis, G. S. 130, 310
Al-Sabban, M. S. 120
Al-Samarrie, A. 130, 430
Alterman, J. 110, 720
Alton, T. P. 100, 050
Alvarez, F. 130, 940
Alvarez-Rents, L. R. 100, 200
Amach, H. M. 110, 440
Amery, A. D. 130, 510
Amir, E. K. 110, 130
Amon, E. 120, 110
Amsden, A. H. 120, 620
Andersen, G. A. 100, 400
Andersen, R. R. 120, 320
Anderson, E. A. 120, 300
Anderson, E. E. 130, 210
Anderson, L. F. 110, 120
Anderson, M. S. 110, 710
Anderson, R. N. 120, 720
Annable, J. E. 130, 820
Annez, P. C. 110, 400
Anthony, R. 160, 850
Anyetei, S. 110, 610
Appleford, D. 130, 530
Arachie, S. C. 110, 710
Arant, W. D. 130, 520
Archibong, P. E. 120, 720
Aremu, D. A. 120
Argodale, R. J. 130, 210
Armida, D. 110, 810
Armstrong, J. 120, 110
Arndt, H. H. 130, 020
Arnold, R. 130, 220
Arouca, L. F. 100, 000
Arrasga-Rodas, L. E. 110, 530
Askin, A. B. 130, A00
Assaley, L. A. 110, 320
Assarsson, B. O. 130, 020
Assis, C. A. 110, 210
Athinaios, A. 110, 210
Auchter, E. L. 110, 400
Auer, J. F. 120, 430
Ault, D. E. 120, 620
Austin, L. A. 130, 210
Awan, M. M. 110, 440
Axilrod, E. 120, 520
Ayal, E. B. 110, 050
Ayre, P. I. 120, 430
Azariadis, C. C. 130, 820
Baanante, C. A. 120, 210
Babylon, J. R. 110, 440
Bachman, M. C. 120, 210
Bacon, D. C. 120, 310
Baek, S. 100, 200
Baer, D. E. 110, 430
Baer, W. 110, 430
Baguley, R. W. 130, 430
Baily, M. N. 100, 820
Baird, W. J. 130, 720
Baker, A. G. 130, 210
Bakker, S. 110, 210
Balabkins, N. W. 120, 050
Balakrishnan, G. 110, 120
Ball, R. J. 130, 210
Ballance, R. H. 110, 420
Bang, C. Y. 110, 310
Baratz, R. Z. 110, 220
Barber, E. L. 120, 440
Barcus, R. H. 130, 210
Barkocy, J. J. 130, 010
Barlow, R. 120, 320
Barrett, M. R. 110, 520
Bartell, E. 110, 850
Barth, H. A. 120, 840
Bassie, V. L. 130, 300
Batchelder, A. B. 110, 410
Bates, L. W. 110, 400
Bausell, C. W., Jr 110, 720
Bax, L. G. 110, 120
Beale, H. B. R. 110, 610
Beare, J. B. 130, 010
Beazley, R. I. 100, 730
Becker, C. M. 110, 320
Becker, H. 130, 520
Beckman, J. 110, 720
Beem, E. R. 110, 030
Beetham, R. C. 130, 520
Beharie, N. O. 110, 120
Behrman, J. R. 120, 110
Bekker, K. 100, 400
Belchere, W. C. 120, 210
Beleky, L. P. 100, 010
Bellale, J. T. 110, 130
Bell, R. M. 110, 130
Bellemore, D. H. 130
Belzile, G. A. 130, 310
Bendt, D. L. 130, 320
Bennett, J. P. 130, 520
Bennett, P. B. 130, 010
Bennett, R. L. 110, 310
Berg, E. J. 110, 120
Berger, F. S. 120, A00
Bergstrom, V. 110
Berlage, L. J. J. 110, 120
Bernanke, B. S. 130, 020
Berry, R. A. 110, 120
Berthomieu, C. 100, 000
Betancourt, R. R. 100, 210
Beveridge, H. S. 130, 210
Beyer, J. C. 110, 610
Bhalla, B. 130, 430
Bhalla, S. S. 100, 920
Bhargava, A. 100, 210
Bhuyan, A. S. 110, 710
Bianco, A. 110, 120
Bieler, T. A. 110, 120
Biggs, R. M. 130, 300
Biggs, T. S. 120, 710
Bigsten, A. 120, 820
Bilkey, W. J. 110, 440
Birch, S. 110, 120
Biswas, B. 110, 410
Bivin, D. G. 130, 210
Blackton, J. S. 110, 710
Blair, C. P. 120, 430
Blanchard, O. J. 130
Blankmeyer, E. 110, 210
Blass, W. P. 110, 610
Blau, D. M. 100, 800
Blitzer, C. R. 100, 720
Bloch, P. C. 120, 820
Blomquist, A. G. 110, 010
Blond, D. L. 110, 320
Bober, S. 110, 130
Boehne, E. G. 130, 310
Boinick, B. R. 120, 300
Bon, R. 110, 050
Bonaparte, T. H. 120, 510
Bonelli, R. 110, 610
Bongard, G. J. 110, 130
Bonitsis, T. H. 100, 400
Bonnel, R. 120
Bonney, D. R. 130, 010
Boomgard, J. J. 120, 710
Borner, S. 130, 440
Bos, H. C. 110, 400
Boschan, C. F. 130, 810
Bosschor, R. A. 120, 940
Bourguignon, F. 110, 210
Bourne, C. 100, 310
Boutros-Ghali, Y. 100, 400
Bower, L. L. 120, 400
Bowers, D. A. 130, 310
Bowman, C. T. 100, 210
Boyer, R. A. 130, 830
Bradford, C. I., Jr 110, 430
Brand, W. 100, 440
Braulke, M. 110, 020
Brazell, D. W. 130, 300
Bredo, W. 100, 430
Breen, F. L. 110, 120
Bremer, J. A. 110, 710
Brenneglass, A. C. 100, 440
Bressand, A. 130, 430
Brill, D. H. 130, 310
Broida, A. L. 130, 310
Brown, G. H. 110, 220
Brown, J. A., Jr 110, 610
Brown, W. V. 110, 320
Browne, B. A. 120, 610
Brownlee, R. H. 110, 510
Brownstein, V. C. 130, 430
Brox, J. A. 130, 310
Bru-Bautista, E. M. 110, 820
Bruce, L. L. 120, 220
Bruch, M. 110, 600
Bruton, H. J. 120, 110
Bry, G. 130, 940
Bulter, W. H. 130, 430
Bull, V. A. 110, 520
Bullen, G. C. 130, 300
Bunjun, S. 110, 940
Burk, M. 110, A00
Burke, R. V. 110, 430
Burke, T. E. 120, 440
Burke, W. M. 130, 940
Burress, G. E. 130, 300
Bushe, D. M. 130, 210
Buttrick, J. A. 110, 020
Byass, R. 120, 210
Byun, H. Y. 110, 130
Cabanilla, N. S. 130, 310
Caceres, L. R. 110, 210
Cadet, M. 100, 200
Callison, C. S. 120, 020
Calvo, G. 110, 310
Campbell, B. O. 100, 430
Campbell, D. A. 130, 320
Campbell, E. J. 130, 210
Campos-Salas, O. 110, 420
Canelias, A. A. 110, 610
Cann, K. T. 120, 130
Cantor, D. J. 130, 440
Caparis, E. A. 120, 930
Caramanis, M. C. 110, 720
Carlip, V. M. 120, 420
Carlson, J. A. 130, 210
Carlson, J. P. 130, 300
Carlson, R. E. 120, 000
Carney, P. W. 120, 410
Carrizosa, J. F. 120
Carson, J. G. 130, 210
Carter, L. 120, 630
Carter, N. G. 100, 440
Carvalho Filho, E. D. 130, 430
Casella, C. 110, 320
Casetti, E. 110, 210
Casinader, L. W. 110, 810
Casperson, P. R. 100, 610
Castellanos-Azpu, M. 110, 820
Castillo, A. 110, 210
Castillo, E. 100, 630
Castronova, F. C. 130, 210
Catto, V. 130, 210
Cavalieri, D. 110, 020
Cave, R. C. 130, 920
Cazell, G. F. 110, 020
Cecchetti, S. G. 130, 820
Cecen, A. A. 110, 210
Cesarini, G. D. A. 110, 020
Chai, C. H. 110, 120
Chaib, A. E. 120, 400
Chakraborta, R. K. 110
Chambers, D. 130, 610
Chambers, E. J. 130, 810
Chang, N. C. 120, 210
Chang, P. P. 120, 440
Chan-Lee, J. H. 130, 720
Chapman, R. W. 110, 610
Charles, K. J. 100, 000
Chatha, P. S. 120, 000
Chau, L. 120, 930
Chaudhry, M. D. 120, 840
Chen, E. K. Y. 110, 620
Chen, T. 110, 620
Chenery, H. B. 110, 400
Chernichovsky, D. 120, 920
Chernick, S. E. 120, 820
Chesler, N. 110, 210
Child, F. C. 120, 400
Childs, G. L. 130, 210
Ching, W. R. H. 110, 220
Chisholm, R. K. 130, 300
Chiswick, C. U. 110, 800
Cho, D. W. 130, 200
Choi, I. 110, 430
Chong-Ma, B. 120, 310
Chossudovsky, M. J. 120, 000
Chou, V. K. 130, 520
Chow, F. C. 110, 720
Chow, P. C. 100, 400
Christen, M. A. 110, 420
Chung, J. S. 110, 210
Chung, K. 110, 440
Chung, Y. 100, 010
Church, P. E. 110, 420
Cicarelli, J. S. 130, 620
Cifuentes, L. A. 130, 000
Cigliano, J. M. 130
Ciolfi, O. 130, 030
Clare, G. 110, 410
Clark, D. C. 110, 820
Clark, E. 130, 310
Clark, P. G. 110, 440
Clever, P. 130, 050
Clifton, D. S. 120, 410
Clifton, J. A. 130, 610
Cline, W. R. 110, 400
Cobbe, J. H. 100, 400
Cock-Londono, J. 110, 520
Code, P. 110, 520
Cody, P. M. 110, 440
Coe, D. T. 130, 210
Cogan, L. P. 130, 1913
Cohen, A. 120, 110
Cohen, M. 130, 220
Cohen, N. P. 120, 440
Cohn, S. H. 120, 050
Coldwell, C. I. 120
Cole, D. C. 100, 300
Cole, H. E. 100, 800
Cole, L. M. 110, 600
Cole, R. E. 130, 210
Cole, W. E. 110, 620
Coleberd, R. E. 130, 220
Colledge, R. J. 100
Combs, E. F. 110, 820
Condit, L. F. 130, 720
Conerly, W. B. 100, 300
Conlan, D. R. 130, 000
Connor, C. H. 120, 420
Constancio, V. M. R. 110, 310
Conte, M. A. 110, 050
Cook, P. D. 120, 940
Cooper, C. A. 100, 400
Cooper, F. L. 130, 210
Copithorne, L. W. 100, 720
Corbin, P. B. 110, 120
Corkhill, R. J. 130, 510
Cornelisse, P. A. 110, 120
Cornilleau, G. 130, 940
Cornwall, J. 110, 130
Corrigan, T. W. 100, 400
Cosgrove, M. H. 100, 900
Costello, W. E. 130, 000
Cotter, P. S. 110, 310
Coutevas, S. D. 120, 930
Coutsoumaris, G. P. 100, 610
Covarrubias, A. 110, 510
Cover, J. H. 100, 420
Cownie, J. 100, 000
Craig, J. T. 110, 440
Crane, G. M. 130, 220
Crary, D. B. 130, 310
Craven, J. H. 130, 310
Crick, N. B. 110, 120
Crockett, C. F. 110, 220
Crosswell, M. 110, 120
Croushore, D. D. 130, 820
Cruzado, J. 100, 300
Cukierman, A. 130, 210
Cukok, B. 100, 600
Cullity, J. P. 100
Cummings, J. T. 120, 440
Cummins, P. A. 130, 940
Curley, M. L. 130, 520
Current, M. D. 130, 050
Curtis, J. W., Jr 100, 930
Curtis, R. V. 110, 710
Czirjak, L. 100, 400
Da Gama Santos, M. 120, 630
Daly, R. F. 130
Daniels, M. G. 100, 400
Daoust, J. P. 100, 400
Dapice, D. O. 110, 120
Darity, W. A. 100, 300
Darling, A. H. 120, 110
Dastidar, S. S. 110, 210
Daubon, R. E. 120, 840
Davenport, P. 110, 130
Davea, T. E. 110, 720
David, W. L. 110, 420
Davinic, M. Z. 110, 220
Davis, J. R. 120, 130
Davis, P. S. 110, 720
Davis, S. J. 130, 310
Dayhim, H. 110, 210
Dean, A. J. H. 130, 800
Deaver, R. M. 130, 010
DeBoers, J. S. 120, 440
Dederick, R. G. 130, 310
DeForest, J. D. 110, 010
Degrogori, T. R. 120, 040
de Jamatta, J. M. 120, 720
Dekock, J. 120, 940
Delancey, V. 120, 840
DeMenil, G. 130, 210
Denison, E. F. 110, 220
Dennis, C. D. 130, 320
De Oliveira, J. C. 110, 440
Desai, N. 110, 720
Desouza, J. G. 100, 400
Dethier, J. 120, 410
Deuster, P. R. 100, 400
Deville, P. R. 110, 820
Devine, J. N. 130, 110
Deyoretz, D. J. 120, 840
Dhaliwal, S. S. 110, 210
Dhanji, F. 120, 440
Diaz-Lopez, F. 110, 820
Dickey, G. E. 110, 720
Diktaban, H. 130, 400
Diller, J. E. 110, 210
Dino, R. N. 130, 430
Dinour, D. 110, 420
Dirk, P. 110, 320
Ditchett, H. S. 110, 020
Diwan, R. K. 110, 620
Dixon, F. T. 130, 210
Dobson, W. 100, 800
Dolde, W. 130, 920
Dolgoy, S. 130, 010
Dominique, C. R. 110, 630
Donald, G. 100, 400
Donaldson, L. 110, 440
Donges, J. B. 100, 400
Donovan, W. G. 120, 710
Doody, F. S. 130, 830
Dorries, W. L. 110, 820
Dosik, R. S. 100, 440
Doss, V. 110, 310
Dowling, E. T. 110, 210
Dragoo, P. E. 110, 510
Dudik-Gayoso, J. B. 100, 440
Due, J. M. 120, 710
Duffy, J. M. 130, 930
Dumoulin, D. C. 110, 940
Duncan, P. D. 110, 620
Dunham, A. D. 130, 210
Dunleavy, K. G. 130, 210
Dunn, E. S. 120, 220
Duringer, J. C. 130, 520
Durkan, J. 130, 120
Durosier, A. 110
Durr, E. 110, 130
Dutt, A. K. 110, 400
Duymovic, A. A. 170, 420
Dvorak, I. D. 120, 620
Dworkin, M. G. 130, 200
Dykema, E. R. 110, 030
Dym, S. 130, 310
Dziadek, F. 110, 430
Earl, P. H. 130, 200
Earley, M. F. 130, 430
Easley, M. L. 110, 220
Eaton, E. D., Jr 100, 500
Ebanks, W. W. 130, 820
Eberhardt, B. M. E. 110, 940
Eckaus, R. S. 110, 120
Eckley, R. S. 130, 420
Eckstein, P. C. 110, 130
Eckstein, Z. 100, 700
Eddin, M. E. 110, 210
Eddison, J. C. 110, 440
Edmonds, J. A. 110, 840
Edwards, E. O. 110, 540
Eggert, R. J. 130, 060
Eichenbaum, M. S. 130, 210
Eickhoff, M. K. 130, 630
Eiland, M. D. 120, 420
Eilert, J. W. 130, 520
Eisenpreis, A. 110, 530
Eklund, P. A. 100, 400

Ekpo, A. H. 110, 940
Elavia, T. H. 130, 210
Elder, F. T. 110, 210
Elliott, H. J. C. 120, 710
Elliott, J. A. M. 120, 020
Elliott-Jones, M. F. 130, 630
Ellis, H. S. 120, 130
El Mallakh, R. 110, 120
Elwell, C. K. 130, 200
Empey, W. F. 130, 940
Engberg, H. L. 120, 430
England, S. F. 130, 320
English, J. M. 100, 520
Entin, S. J. 100, 400
Epps, M. L. 110, 420
Epstein, J. D. 120, 430
Erickson, R. C. 110, 940
Eriksson, J. R. 120, 440
Erlich, A. 110, 030
Erlichster, J. 110, 130
Erselcuk, M. M. 120, 440
Escober, G. J. 130, 720
Espinel, R. L. 110, 420
Essig, J. L. 130, 400
Ethier, M. 130, 060
Ettinger, S. J. 110, 410
Evans, G. 130, 210
Evans, G. S. 130, 420
Evenson, R. E. 110, 710
Everett, R. W. 130, 320
Ezzani, E. C. 100, 400
Fabricant, S. 110, 130
Fairchild, L. 120, 320
Falcon, N. D. 110, 420
Famadas, J. 120, 440
Fan, Y. 110, 020
Farah, G. T. 110, 930
Fardi, M. A. 100, 400
Farley, R. 110, 930
Farrell, M. J. 120, 310
Fasenfest, D. 120, 420
Fawundu, F. G. 110, 020
Fayissa, B. 110, 210
Feder, G. 100, 440
Feinn, B. A. 100, 210
Feldman, S. J. 130, 210
Felix, D. 110, 120
Fels, A. H. 130, 820
Fernandez, J. C. 120, 400
Ferster, G. 110, 700
Feser, H. 110, 910
Fiedler, E. R. 130, 300
Field, A. J. 110, 400
Field, R. M. 120, 630
Fields, T. W. 130, 210
Fienup, D. F. 120, 710
Filippello, A. N. 130, 010
Filippone, E. F. 110, 720
Findley, G. D. 120, 800
Fine, S. M. 110, 120
Finn, B. P. 110, 940
First, R. K. 130, 200
Fischer, D. 110, 440
Fisher, P. M. J. 110, 210
Fishlow, A. 120, 040
Fishman, L. 100, 200
Flam, H. 110, 410
Fletcher, L. P. 110, 320
Flint, H. D. 130, 310
Flores, E. 110, 620
Flores, M. 110, 310
Fluker, J. R. 110, 440
Fontana, P. 130, 210
Forrest, S. 110, 010
Fortin, P. 130, 820
Foss, M. F. 130, 000
Fox, J. W. 110, 420
Fox, L. P. 110, 410
Frank, C. R., Jr 100, 400
Frank, W. T. 100, 020
Frankel, M. 100, 600
Frankman, M. J. 120, 420
Fraser, J. L. 110, 130
Frechtling, J. A. 130, 110
Frederiksen, P. C. 120, 610
Fricke, C. V. 130, 520
Frijas, J. M. G. 100, 210
Friscia, A. B. 120, 430
Fritz, W. G. 120, 720
Fry, M. J. 120, 310
Frye, J. 130, 310
Fuerst, A. M. 110, 930
Furst, E. 130, 310
Gagnon, D. 120, 630
Gahlen, B. 130, 020
Gajewski, P. 100, 700
Galenson, A. C. 110, 040
Galetschky, H. 110, 010
Gapinski, J. H. 130, 210
Garbecz, C. 120, 940
Garcia-Huidobro, G. 100, 800
Garfield, F. R. 130, 220
Garganas, N. C. 130, 010
Garlow, D. C. 110, 020
Garon, E. Y. 100, 400
Garrity, M. P. 120, 420
Garston, N. H. 130, 800
Gary, H. C. 120, 440
Gately, D. 110, 210
Gay, R. S. 130, 820
Gayoso-Quintana, A. 110, 710
Geithman, D. T. 120, 010
Gelber, F. 130, 820
Genetski, R. J. 130, 310
Gerrard, C. 110, 710
Gershenberg, I. 110, 440
Gersovitz, M. 120, 020
Gharrity, N. J. 130, 400
Ghatak, S. 110, 120
Gibb, A., Jr 120, 940
Gibson, W. B. 120, 440
Gidwani, S. J. 110, 050
Gierach, H. 100, 400
Gifford, B. R. 110, 320
Gilbert, F. E. 110, 440
Gillis, S. M. 110, 320
Ginestar, A. 110, 010
Ginor, F. 120, 910
Girao, J. A. 130, 210
Girardbille, S. 120, 900
Girgis, M. 120, 420
Giroux, P. 110, 940
Gittinger, J. P. 110, 000
Glasser, R. 120, 440
Glatthar, G. E. 110, 120
Gleason, A. H. 120, 040
Glennon, J. J. 120, 630
Glennon, W. B. 110, 940
Glezakos, C. 110, 210
Glover, F. J. 110, 420
Glytsos, N. P. 100, 820
Gochenour, J. G. 110, 120
Godfrey, J. M. 130, 310
Goetz, R. 130, 520
Goff, E. F. 130, 830
Gogerty, D. C. 110, 630
Gomez-D'Angelo, W. 120, 220
Gonzalez-Martinez, A. 110, 020
Goode, J. H. 100, 800
Goodwin, W. B. 100, 630
Gordon, D. L. 110, 440
Gordon, L. 110, 440
Gorgens, E. 100, 600
Gormely, P. J. 110, 120
Gottfried, R. R. 120, 940
Gottfries, C. G. N. 130, 430
Gould, L. B. 130, 310
Graber, E. S. 110, 520
Grabowski, R. L. 110, 410
Graham, D. H. 120, 840
Grais, W. 110, 200
Grandstaff, P. J. 130, 840
Granelle, J. J. 130, 930
Grannatt, M. H., III 130, 940
Grawe, R. W. 120, 400
Gray, A. L., Jr 110, 830
Gray, C. S. 110, 440
Green, G. R. 130, 210
Greenspan, A. 130, 300
Greenwald, D. 130, 220
Greenwood, M. A. 110, 520
Greer, J. S. 100, 210
Gregory, M. B. 130, 830
Griffin, J. M. 130, 310
Grommet, A. C. 110, 400
Grossman, E. S. 130, 200
Grossman, M. C. 110, 400
Grude, W. A. 130, 520
Grunwald, J. 120, 420
Guest, J. F. 110, 210
Guillaumont, P. 110, 440
Gunden, R. G. 110, 420
Gunderson, R. J. 100, 940
Gunyou, J. M. 120, 320
Gupta, H. C. 110, 120
Guria, J. C. 110, 210
Gusau, G. I. 110
Gusen, P. 130, 940
Guthrie, T. L. 130
Gutierrez, E. G. 120, 520
Gutierrez-Santos, L. E. 110, 720
Gutman, J. 110, 930
Gutowsky, A. R. 130, 020
Gyimah-Brempong, K. 120, 930
Gylfason, T. 130, 430
Hadjiantoniou, G. P. 110, 520
Hagedorn, G. G. 130, 020
Hagen, E. E. 110, A00
Hailstones, T. J. 130, 110
Hakim, L. D. 110, 720
Halcrow, R. B. 110, 720
Haldane, E. A. R. 130, 430
Haldeman, K. B. 130, 310
Halim, M. C. 110, 840
Hall, B. 130, 300
Hall, R. E. 130, 820
Hamada, T. 120, 420
Hamm, K. K. 120, 940
Hammelton, R. L. 110, 440
Hammer, J. S. 110, 410
Hanni, E. A. 130, 310
Hannigan, S. R. 130, 940
Hanselman, W. C. 120, 200
Hansen, B. 110, 300
Hansen, H. G. 120, 130
Hansen, S. 100, 900
Hanson, J. A. 110, 430
Haraf, W. 130, 310
Harber, R. P. 110, 320
Hard, G. W., Jr 110, 510
Hardouvelis, G. A. 130, 210
Hardy, R. W. 100, 400
Harik, B. E. 110, 310
Harman, P. W. 120, 430
Harms, L. T. 110, 810
Harmston, F. K. 120, 940
Harpet, G. A. 130, 530
Harral, C. G. 120, 630
Harriff, R. B. 110, 520
Harris, J. J. 120, 320
Harris, J. R. 120, 930
Harris, J. W. 110, 430
Harris, M. C., Sr 130, 520
Harris, R. I. D. 110, 220
Harrison, J. Q. 100, 710
Hart, A. G. 130, 310
Hart, J. W. 120, 640
Hartford, D. J. 110, 440
Hartley, P. R. 130, 430
Hartzell, J. K. 110, 440
Haruta, H. 110, 930
Harwitz, M. 110, 940
Hasa, H. 110, 620
Hassan, M. F. 110, 420
Hassinger, A. B. 120, 430
Hassler, H. C. 130, 710
Haughey, J. W. 130, 500
Haughton, J. H. 120, 400
Hauser, M. A. 110, 530
Havrylyshyn, O. 100, 400
Hawkins, E. K. 110, 840
Hay, G. A. 100, 400
Hayes, S. P. 120, 440
Hayworth, S. C. 110, 320
Head, T. F. 110, 120
Healy, M. E. 130, 320
Heim, G. A. M. 110, 430
Helfers, W. L. 100, 200
Hella, K. N. 120, 940
Hellemaim-Ashfield, J. R. 120, 420
Helmers, F. L. C. H. 110, 720
Helzner, M. L. 130, 900
Henderson, H. A. 100, 700
Henderson, M. F. 130
Hendry, J. B. 100, 700
Henn, J. K. 110, 120
Henry, C. M. 100, 400
Henry, M. D. 110, 930
Hensley, R. J. 110, 610
Herman, B. M. 110, 430
Herman, L. A. 120, 610
Herrick, B. H. 100, 800
Hersch, A. J. 130, 320
Hess, A. C. 130, 310
Hice, C. J. 110, 210
Hickman, B. G. 130, 210
Hicks, N. L. 100, 400
Hihn, J. M. 110, 210
Hill, R. W. 130, 520
Hillabold, A. B. 110, 030
Hirsch, A. A. 130, 210
Hirschhorn, E. L. 130, 310
Hirschman, A. O. 120, 000
Ho, S. P. S. 120, 110
Ho, Y. 120, 220
Ho, Y. 120, 420
Hobbs, K. A. 130, 920
Hodes, D. A. 130, 520
Hodgson, C. W. 110, 640
Hoelscher, D. S. 120, 440
Hoelscher, G. P. 130, 310
Hoey, R. B. 130, 310
Hoffmann, C. 110, 800
Hogendorn, J. S. 120, 040
Hogg, V. W. 120, 630
Hokabergen, R. G. 120
Holben, R. E. 110, 610
Hollman, K. W. 130, 310
Holsen, J. A. 100, 400
Holt, C. F. 130, 040
Holy, V. L. d. P. 100, 430
Hondal, S. 120, 710
Hooley, R. 100, 400
Hopenhayn, B. R. 110, 030
Hopkins, R. G. 130, 210
Horiuchi, S. 120, 630
Horvath, J. 110, 120
Hossain, I. 120, 130
Hottenstein, D. 110, 720
Hou, C. 120, 440
Houwink, W. 110, 030
Howard, A. L. 110, 810
Howland, J. E. 120, 400
Hsiao, F. S. T. 110, 210
Hsu, J. C. Y. 110, 410
Hsu, R. C. 120, 400
Hsueh, T. 120, 320
Huang, Y. 120, 110
Hubert, J. H. 110, 310
Huddle, D. L. 100, 800
Huenemann, R. W. 110, 050
Huff, W. G. 120, 040
Hughes, K. B. 130, 610
Hughes, P. R. M. 110, 930
Hul, G. W. L. 130, 310
Hulsman, S. 110, 020
Humphreys, C. P. 120, 710
Hunt, S. J. 120, 040
Hunter, H. 110, 050
Hunter, J. M. 110, 120
Huq, M. 120, 110
Hurlebaus, J. F. 110, 720
Hutchinson, E. C. 120, 110
Hybels, J. H. 130, 940
Hyde, G. L. 100, 430
Imai, T. 110, 210
Immerdauer, B. 110, 120
Imolati, L. 130, 210
Infante, E. 110, 130
Irish, W. F. 110, 210
Irvine, F. O. 130, 210
Isachsen, A. J. 110, 310
Isbister, J. 110, 840
Ishaq, A. M. 120, 130
Ishikawa, S. 110, 120
Islam, S. 120, 440
Islam, S. 100, 430
Itam, S. P. O. 120, 430
Jackson, C. J. 130, 210
Jackson, G. L. 130, 610
Jacques, M. 100, 610
Jadhav, A. G. 100, 500
Jaffe, M. I. 130, 220
Jakubiak, H. E. 110, 300
Jakubiak, S. 100, 200
James, M. G. 120, 210
James, W. E. 120, 710
Jameson, K. P. 100, 020
Jannuzi, F. T. 120, 040
Jansen, D. J. 100, 710
Jaquette, P. B. 130, 210
Jarvis, L. S. 120, 710
Jaspersen, F. Z. 110, 630
Jenner, R. A. 120
Jennings, F. N. 130, 310
Jensen, F. 100, 200
Jermain, D. O. 110, 730
Jess, M. J. 130, 210
Jessee, D. L. 110, 700
Jessup, L. E. 130, 320
Jianakoplos, N. A. 130, 310
Jochimsen, R. H. H. 110, 940
John, K. 130, 830
Johnson, J. H. 110, 400
Johnson, M. A. 110, 120
Johnson, O. E. G. 120, 020
Johnson, R. D. 110, 410
Johnson, W. A. 110, 210
Johnson, W. F. 110, 710
Johnston, B. F. 110, 710
Johnston, T. D. 120, 710
Jolly, A. R. 120, 850
Jones, J. F. 100, 800
Jones, L. P. 110, 610
Jones, R. C. 110, 850
Jones, R. J. 110, 850
Jonson, P. D. 130, 430
Jordan, R. E. 120, 440
Joshua, M. S. 110, 000
Jouvenel Ursins, B. d. 110, 040
Jozak, J. A. 110, 130
Juba, B. M. 130, 430
Jung, C. 110
Jussawalla, M. F. 110, 420
Kadekodi, G. K. 110, 210
Kagann, S. 130, 300
Kahf, M. N. 110, 410
Kakazu, H. 120, 410
Kalicki, S. F. 130, 820
Kalver, L. C. 130, 210
Kamarck, A. M. 110, 940
Kamrany, N. M. 100, 620
Kanamori, H. 130, 420
Kane, J. A. 130, 500
Kaneda, H. 120, 620
Kao, C. H. C. 110, 810
Karfunkle, R. D. 130, 630
Kariotis, T. C. 120, 000
Karkar, Y. N. 120, 040
Karr, W. I. 110, 620
Kaser, M. C. 110, 420
Kasper, V. 110, 720
Katardisastra, W. 110, 120
Kato, H. 130, 310
Kato, M. 110
Kattermann, D. 110, 400
Katz, S. M. 100, 710
Katz, S. S. 110, 440
Katzen, L. 120, 130
Kaufman, S. E. 130, 440
Kavesh, R. A. 130, 310
Kawahito, K. 110, 410
Keane, M. 100
Keddeman, W. D. 100, 710
Keenan, D. 120, 520
Kelley, A. C. 100, 840
Kelley, J. 120
Kelley, J. W. 130, 610
Kellner, I. L. 130, 310
Kempff-Mercado, R. 110, 010
Kenadjian, B. 110, 220
Kenessey, Z. E. 110, 220
Kennedy, C. A. 110, 430
Kennedy, D. D. 110, 440
Kennedy, K. A. 110, 300
Kennedy, M. C. 130, 320
Kennedy, W. T. 130, 520
Kestell, R. J. 100, 400
Keyserling, L. H. 100, 300
Khan, A. A. 130, 440
Khan, M. H. 110, 120
Khurman, A. A. 110
Kieschnick, M. F. 110, 320
Kilby, P. 120, 620
Kim, k. H. 120, 020
Kim, I. 110, 430
Kim, Y. C. 110, 020
Kim, Y. K. 120, 630
Kim, Y. S. E. 120, 420
King, A. T. 110, 320
Kinsey, B. H. 100, 700
Kipnis, G. M. 130, 700
Kirkpatrick, C. H. 100, 400
Kisa, J. J. 110
Kisyman, M. I. 100, 400
Klein, P. A. 130, 300
Klein, S. 120, 130
Klots, B. A. 130, 210
Klotz, B. P. 130, 210
Knapman, B. 120, 040
Knapp, J. W. 110, 720
Knapp, R. W. 130, 610
Knauerhase, R. 110, 040
Knight, J. B. 120, 800
Knight, P. T. 110, 610
Knoop, H. G. 110, 840
Knowles, J. W. 130, 300
Knudsen, O. K. 110, 400
Kocher, J. E. 120, 840
Koellreuter, C. 130, 630
Koenig, L. M. 130, 310
Koenig, W. 100, 400
Kofi, T. A. 100, 220
Kolp, P. W. 110, 630
Kondonassis, A. J. 110, 040
Koop, P. A. 120, 610
Koropeckyj, I. S. 110, 030
Kotwal, A. Y. 110, 620
Koulourianos, D. 110, 810
Kouwenaar, A. 110, 420
Koziebrodzki, L. B. 120, 320
Kozlowski, P. J. 130, 940
Kramer, C. 110, 020
Kraus, W. 120, 110
Kregel, J. A. 110, 310
Kreider, L. E. 130, 310
Krentz, D. S. 130, 210
Kresge, D. T. 110, 940
Kristof, F. S. 120, 110
Kromphardt, J. 130, 110
Kropp, F. G. 120, 210
Kruisinga, J. D. M. 130, 610
Kubecki, T. 110, 210
Kubo, Y. 120, 110
Kubota, K. 110, 210
Kuczynski, P. 120, 320
Kuh, C. V. 130, 820
Kuhn, W. E. 120, 430
Kumar, R. 110, 420
Kumassah, L. K. 120
Kuntz, D. F. 100, 300
Kuntz, D. L. 130
Kuperberg, M. J. 130, 310
Kutnick, B. L. 110, 620
Kutscher, R. E. 110, 210
Kuznets, P. W. 120, 220
Kuznets, S. S. 110, 620
Kydland, F. E. 130, 610
Lachler, U. 130, 020
Lacroix, R. 130, 620
Laden, B. E. 130, 010
Ladman, J. R. 120, 710
LaGace, G. L. 100, 400
Lageman, B. 120, 050
Laidler, D. E. W. 130, 030
Lajous, A. 110, 720
Lal, D. K. 100, 400
Landau, D. L. 110, 010
Landsberger, P. D. 130, 010
Lanfranco, S. L. 110, 420
Langfeld, J. H. 110, 030
Lanvin, B. D. 110, 210
Laposata, S. M. 130, 810
Lari, E. F. 120, 440
Larimer, J. R. 120, 130
Larmann, D. 110, 720
Larsen, F. 130, 320
Latortue, P. R. 120, 810
Latouretta, J. E. 110, 130
Laumas, P. S. 110, 020

Lauterbach, A. 110, 050
Lawson, S. J. 110, 400
Leaverton, K. V. 110, 930
Lecaros, F. 120
Lecraw, D. J. 100, 600
Lee, C. H. 110, 220
Lee, J. W. 130, 220
Lee, M. K. S. C. 110, 120
Lee, M. W. 130, 320
Lee, P. 110, 210
Lee, S. 110, 000
Lee, S. A. 110, 320
Leff, N. H. 120, 440
Leggitt, A. C. 100, 400
Leitner, R. E. 130, 210
Leiovitis, L. 110, 520
Lempert, L. H. 130, 220
Leon, P. 110, 400
Lepas, A. G. 100, 600
Levin, J. E. 110, 410
Levy, F. D. 110, 120
Levy, P. 130
Levy, S. 110, 810
Lewin, K. I. 130, 420
Lewis, J. P. 110, 440
Lewis, M. A. 100, 840
Lewis, R. E. 130, 220
Lewis, S. R. 110, 320
Lewis, W., Jr 100, 300
Lewis, W. A. 110, 120
Ley, R. D. 110, 720
Liang, K. 120, 420
Liedholm, C. E. 120, 410
Light, J. M. 130, 210
Lillydahl, J. H. 120, 820
Lim, G. 110, 930
Lim, Y. 120, 420
Lin, C. 100, 400
Lin, W. 110, 220
Lindeman, W. O. 120, 940
Lindsey, C. W. 120, 400
Lindskog, D. C. 130, 210
Linnemann, H. 110, 420
Lippit, V. D. 120, 050
Lippke, B. R. 130, 520
Liu, D. W. P. 110, 020
Liu, J. 120, 000
Liu, S. F. 120, 520
Livingston, J. A. 130, 320
Llosas, H. P. 110, 320
Llueh, C. 110, 920
Lobbe, K. 120, 600
Loehr, W. 100, 400
Loertscher, R. 110, 420
Loftus, J. A. 130, 720
Lohsen, M. A. 110, 620
Long, M. F. 110, 310
Looney, R. 120, 110
Lopes, F. L. 110, 130
Lopez, M. 120, 710
Lotshaw, E. P. 130, 630
Love, J. L. 110, 940
Lovell, M. C. 130, 210
Lowe, A. 110, 020
Lowenthal, P. 130, 320
Lubell, H. 120, 820
Lucas, D. E. 110, 130
Lucas, E. F. 110, 210
Lucas, R. E. 130, 310
Lukas, T. A. 110, 850
Lund, O. M. 110, 210
Lundberg, E. 130, 040
Lustig, N. C. 110, 120
Luther, M. E. 130, 310
Lyons, T. P. 110, 040
Lysy, F. J. 110, 030
Macchio, D. J. 100, 630
MacMillan, B. E. 110, 630
Madewell, C. E. 100, 700
Madigan, D. 100, 800
Madrigal, D. A. 110, 410
Maemone, R. F. 130, 630
Maher, J. J., Jr 110, 020
Mahoney, D. M. 130, 300
Maier, F. H. 110, 710
Maillet, M. P. 110, 420
Makinen, M. 120, 710
Malenbaum, W. 120, 720
Malesh, T. H., Jr 130, 210
Malik, M. A. K. 110, 210
Malion, R. D. 100, 400
Maltezou, S. P. 110, 720
Mamalakis, M. J. 120, 220
Manchester, P. B. 130, 320
Mandlebaum, B. 110
Manescki, A. 110, 410
Manlyar, V. P. 130, 310
Manova, M. 110, 020
Mantell, N. H. 130, 210
Marcuse, W. 110, 720
Margolis, A. 130, 310
Margoshes, S. L. 100, 630
Mark, S. M. 110, 120
Markus, G. 100, 200
Marroquin, J. J. 110, 320
Martens, A. 110, 420
Martin, P. P. 110, 210
Maruyama, Y. 120, 710
Mason, B. B. 130, 210
Mason, E. S. 120, 610
Mathieu, N. 110, 130
Mathur, S. C. 120, 210
Mattart, F. 110, 120
Matthews, W. T. 130, 940
Matthiessen, L. O. 130, 320
May, T. 130, 210
Maydon, F. 120, 310
Mayer, K. M. 110, 520
Mayo, A. L. 110, 430
Mazur, M. P. 120, 400
McAuley, J. J. 130, 410
McCallum, B. T. 130, 310
McCarthy, F. D. 120, 210
McCawley, P. T. 120, 630
McClelland, D. H. 110, 440
McDonald, G. E. 130, 940
McDowell, J. H. 130, 220
McElroy, J. L. 120, 940
McFarland, W. E. 110, 720
McFarland, W. F. 130, 210
McGaughey, S. E. 120, 710
McGreevey, W. P. 120, 840
McGurl, V. W. 120, 520
McIlwain, B. A. 100, 400
McKee, M. J. 130, 210
McKelvey, M. J. 130, 210
McKinley, D. H. 130, 310
McKinsey, J. W. 110, 840
McKnight, J. 130, 630
McLaughlin, R. U. 120, 440
McLean, A. A. 110, 210
McLoughlin, P. F. M. 120, 720
McMahon, W. W. 130, 850
McMillan, T. E. 130, 020
McPherson, W. W. 110, 710
Mead, D. C. 110, 630
Meers, L. A. 110, 710
Meeks, T. J. 100, 200
Meesook, K. M. 130, 940
Mehmet, O. 120, 420
Mehrabi, S. M. 120
Mehran, F. 120, 400
Mehran, H. 100, 300
Mellor, J. W. 110, 710
Mendels, R. P. 110, 320
Mendez, J. A. 120, 410
Mennes, L. B. M. 100, 400
Menzier, G. 110, 120
Merrill, W. C. 120, 610
Mesa-Lago, C. 120, 050
Metzger, J. E. 110, 800
Meyer, P. B. 110, 820
Meyers, K. K. 110, 210
Mezzadri, F. A. 120, 310
Michael, W. P. 110, 440
Michalopoulos, C. 110, 400
Michel, P. 130, 310
Mikoljon, S. J. 130, 410
Miller, C. L. 110, 050
Miller, D. D. 100, 400
Miller, G. H. 130, 040
Miller, M. 110, 220
Miller, R. M. 110, 530
Miller, S. H. 130, 430
Miller, W. C. 110, 410
Mills, N. B. 110, 940
Miracle, D. S. 110, 710
Miracle, M. P. 120, 710
Misheloff, R. 110, 440
Mitchell, D. B. 120, 440
Mitchell, F. 110, 930
Mitchell, K. 110, 040
Moeller, C., Jr 130, 520
Monette, V. 110, 010
Monroe, M. C. 120, 610
Montanheiro, L. C. 110, 320
Montavon, P. A. 100, 400
Moody, S. K. 110, 520
Moore, G. E. 130, 030
Moore, G. H. 130, 220
Moreira, L. A. 120, 610
Moreno, V. 110, 320
Morgan-Mendez, V. E. 130, 400
Mork, K. A. 130, 210
Morley, S. A. 110, 130
Morreau, J. G. 130, 310
Morris, C. T. 100, 040
Morrison, D. G. 120, 210
Morrisson, C. 120, 320
Morse, K. O. 110, 420
Mosak, J. L. 100, 400
Moser, C. L. 100, 810
Motheral, C. J. 130, 320
Mott, R. T. 120, 940
Moussavian, M. H. 110, 720
Moyano, E. 100, 500
Mudge, J. L. 110, 120
Mudie, J. H. 100, 300
Mullenbach, P. 100, 600
Mulligan, P. F. 110, 710
Mullings, L. M. 110, 410
Multop, J. R. 130, 320
Munasinghe, M. P. 110, 610
Munasinghe, S. N. 110, 610
Mundlak, Y. 100, 210
Murakami, R. 120, 020
Murray, A. P. 130, 320
Murua, R. R. 110, 310
Muscat, R. J. 110, 440
Myers, H. L. 110, 420
Myers, R. B. 110, 400
Nafziger, E. W. 110, 400
Namias, J. E. 130, 210
Nankani, G. T. 100, 200
Naroll, M. 100, 800
Nash, J. D. 100, 320
Nash, J. M. 120, 430
Nathan, H. C. 130, 310
Nathan, R. R. 110, 130
Naylor, W. C. 100, 400
Neal, A. C. 110, 310
Neck, R. 100, 210
Nelson, E. R. 100, 840
Nelson, G. C. 110, 400
Newcomb, R. T. 110, 420
Newmann, J. M. 110, 400
Newton, J. R. 110, 420
Nichols, D. A. 130, 320
Nichols, J. A. 130, 310
Nicoletti, R. V. 130, 210
Nielsen, E. H. 110, 210
Niemira, M. P. 130, 200
Niskanen, W. A. 130, 320
Nitsch, M. 120, 440
Noman, A. 120, 400
Norbye, O. D. 120, 440
Nordhaus, W. D. 130, 720
Norton, F. E. 130, 300
Norton, R. D. 110, 710
Nossier, A. M. A. 110
Novak, G. J. 100, 200
Noyelle, T. J. 110, 820
Nugent, J. B. 110, 420
Nunez, G. E. 120, 050
Oberhofer, T. 110, 320
O'Callaghan, J. 120, 630
O'Carroll, L. T. 130, 630
Ochsner, D. L. 130, 200
O'Connor, P. W. 130, 010
Odaka, K. 120, 820
Oesterlen, B. 100
O'Gara, R. T. 130, 520
Ohashi, K. 120, 210
Ohrenstein, R. A. 130, 030
Okigbo, P. N. 100, 110
Okita, S. 110, 420
Okuda, K. 110, 120
O'Neill, M. P. 110, 720
O'Nuallain, L. 120, 940
Oppel, E. I. 120, 630
Opryszek, P. A. 110, 940
Opyrchal, A. M. 100, 200
O'Rorke, R. J. 130, 520
Oshima, H. T. 110, 000
O'Sullivan, P. J. 120, 410
Ota, T. 120, 440
Otani, R. 110, 130
Over, A. M., Jr 110, 210
Overbeek, J. 120, 840
Oweiss, I. M. 120, 440
Owen, W. F. 110, 710
Owens, J. W. 130, 220
Oyaide, W. J. 100, 440
Oyola, J. R. 110, 410
Oyster, W. E. 100, 610
Paauw, D. S. 110, 120
Pack, H. 120, 110
Pafenberg, F. W. 130, 210
Painter, D. H. 110, 120
Pak, S. J. 130, 310
Pal, I. D. 120, 420
Palmer, R. W. 110, 320
Panagides, S. S. 110, 440
Pandit, R. B. 110, 440
Papademos, L. D. 130, 310
Papadimitriou, D. B. 110, 020
Papanek, G. F. 110, 050
Papi, G. U. 110, 410
Papp, F. R. 130, 630
Paquette, P. H. 110, 720
Parent, B. A. 100, 520
Parent, M. 120, 000
Parera, J. C. 110, 210
Park, J. A. 130, 020
Park, K. 130, 210
Park, Y. J. 110, 020
Parker, D. E. 110, 720
Parr Bond, E. 120, 940
Parsons, K. H. 110, 710
Parvin, M. 110, 210
Pascuchi, F. J. 130, 110
Pastor, A. 110, 720
Patel, M. S. 120, 400
Patrick, H. T. 120, 310
Pattanajidvilai, S. 130, 400
Patterson, P. W. 130, 310
Pauly, P. H. 130, 210
Peach, J. T. 110, 210
Pearson, S. R. 100, 400
Pedersen, P. J. 130, 020
Pendergast, R. A. J. 120, 040
Penndorf, C. H. 100, 400
Pennisi, G. 120, 810
Penrose, E. T. 100, 700
Pepper, T. M. 110, 410
Peret, J. C. G. 130, 300
Peretz, P. 130, 320
Perez-Lopez, J. F. 120, 420
Perez-Valtier, M. A. 130, 630
Perez-Villamil, J. R. 110, 840
Periasamy, P. G. 110, 840
Perkins, D. H. 110, 040
Perkins, J. 100, 440
Perlin, G. L. 100, 300
Perreault, P. T. 110, 120
Perry, G. L. 130, 300
Perry, R. H. 130, 310
Peterson, A. T. 120, 300
Peterson, R. S. 130, 310
Peterson, W. 130, 210
Peterson, W. A. 130, 020
Petitbo, A. 110, 620
Pettoe, J. C. 110, 630
Pettengill, J. S. 130, 820
Phelps, E. S. 100, 300
Phillips, W. G. 120, 610
Philpott, B. P. 110, 120
Phipps, A. J. 130, 830
Picker, A. D. 130, 500
Pina, A. G. G. d. 110, 940
Pineda, J. F. 110, 120
Pinzon, M. C. 110, 410
Piovia, F. 100, 600
Pirnat, J. A. 130, 200
Pitt, M. M. 120, 400
Pitts, M. A. 120, 400
Plasschaert, S. 120, 430
Plowman, E. G. 110, 510
Pomeranz, L. 110, 930
Ponchick, E. A. 130, 310
Ponder, H. 100, 110
Pongo, T. 110, 420
Pool, J. C. 110, 440
Poole, K. E. 110, 320
Popkin, J. 130, 210
Porter, R. C. 120, 720
Portes, R. D. 110, 020
Postma, P. 110, 940
Poulin, M. M. 130, 900
Powelson, J. P. 120, 040
Pranzo, M. L. 110, 940
Preiss, A. R. 130, 210
Prince, R. 110, 720
Pritchett, D. V. 130, 210
Prodromidis, K. P. 110, 020
Proulx, G. 130, 610
Prucha, I. R. 130, 210
Pryor, Z. P. 120, 040
Qusyis, M. J. 130, 910
Quibria, M. G. 110, 020
Radspieler, A. 100, 400
Rahbany, K. P. 110, 500
Rahn, R. W. 130, 410
Raines, F. Q. 130, 810
Ram, R. 120, 800
Ramachandran, R. V. 110, 020
Ramirez-Ocampo, J. 120, 420
Ramirez-Perez, M. A. 110, 220
Ramos, I. 130, 520
Ramser, H. J. 130, 520
Ramuglia, A. I. 120, 730
Ranis, G. 110, 440
Ratajczak, D. 130, 210
Ratajczak, R. 100, 210
Ratner, J. B. 130, 820
Rauner, R. M. 110, 940
Rawski, T. G. 110, 120
Reardon, P. A. 130, 610
Reati, A. 130, 610
Reed, J. P. 110, 510
Reed, R. J. 110, 210
Reeder, C. B. 130, 500
Reeder, C. P. 120, 810
Reedy, J. H. 120, 110
Reinfeld, K. D. 110, 720
Reinfeld, W. 120, 630
Reing, C. H. 100, 720
Reinhardt, N. 120, 040
Rempel, H. 120, 810
Renas, S. M. 130, 840
Renner, D. E. 110, 220
Reno, P. 120, 810
Reubens, E. P. 110, 930
Reynolds, C. W. 100, 400
Reynolds, L. G. 110, 820
Reznik, B. G. 100, 200
Rhee, Y. W. 120, 110
Rhoades, D. 130, 210
Rhodus, W. G. 130, 020
Rice, R. C. 100, 400
Richard, J. S. 120, 910
Richers, R. 110, 530
Riddel, A. 120, 300
Ridker, R. G. 100, 840
Rieffel, A. 110, 430
Ripley, F. C. 130, 210
Rivera-Batiz, F. L. 100, 800
Roach, S. S. 130, 210
Robert, D. F. 110, 440
Robinson, S. 110, 210
Robinson, W. C. 120, 840
Robson, P. 120, 420
Roca, S. 120, 400
Rocha, E. 110, 120
Rochford, S. C. 110, 020
Rockwell, A. E. 130, 520
Roddy, M. G. 130, 210
Rodgers, G. B. 110, 800
Rodgers, J. L. 110, 620
Roemer, M. 100, 400
Roesler, T. W. 130, 200
Rogiers, F. H. F. 110, 050
Roop, J. M. 130, 210
Roppel, U. 100, 800
Rosa, J. 130, 800
Rose, H. 130, 020
Rosen, G. 110, 050
Rosen, S. 130, 220
Rosenberg, R. E. 100, 300
Ross, D. F. 110, 120
Rossi, J. H. 130, 520
Roy, D. A. 110, 440
Ruane, F. P. 110, 820
Rubinyi, P. 110, 500
Ruffing, L. T. 120, 720
Ruiz, A. L. 110, 210
Ruiz, M. 110, 200
Ruiz-Lara, J. 110, 440
Runyon, H. R. 130, 520
Rush, B. 130, 220
Russel, J. M. 130, 210
Ruth, R. L. 130, 520
Ryan, J. S. 120
Ryan, W. F. 100, 060
Ryder, H. E. 110, 210
Ryle, P. M. 120, 000
Saba, G. C. 130, 310
Sabharwal, A. S. 120, 430
Sabrang, H. 120, 050
Sadove, A. R. 120, 060
Sahadi, R. J. 130, 310
Salera, E. L. 110, 120
Sakong, I. 120, 310
Salehi-Isfahani, D. 120, 840
Salgado, G. 110, 120
Salihu, A. 120
Salz, F. 130, 310
Salzman, L. 130, 210
Samli, M. V. 110, 720
Samli, S. 130, 020
Samohyl, R. W. 120, 620
Sampaio, Y. d. S. B. 110, 120
Sanchez, N. 110, 020
Sander, F. W. 110, 210
Sandoka, I. I. 130
Sanguinetty, J. A. 110, 850
Santiago, C. E. 110, 120
Saper, A. M. 110, 440
Sapir, A. 120, 420
Sargent, J. R. 130, 010
Sauniers, A. H. 110, 220
Saunders, N. C. 130, 210
Sawyer, J. A. 130, 210
Scandizzo, P. L. 110, 210
Scanlon, R. 110, 930
Schachter, G. 110, 940
Schaevitz, R. C. 100, 940
Schamper, J. W. 110, 120
Schatz, S. P. 120, 110
Scheibler, D. 110, 220
Schickele, R. 110, 920
Schlotthauer, J. P. 110, 120
Scholvinck, J. B. W. 120, 840
Schreiber, M. M. 130, 940
Schroeder, H. 130, 310
Schuh, G. E. 120, 710
Schulmann, H. 100, 400
Schultheis, M. J. 110, 050
Schultz, R. S. 130, 940
Schultze, C. L. 130, 320
Schydlowsky, D. M. 110, 420
Scott, M. F. G. 100, 400
Scott, T. W. K. 120, 420
Secchi, C. 110, 420
Seeberger, H. M. 110, 310
Segall, N. I. 130, 630
Segredo, M. D. 110, 130
Seidel, E. M. 110, 530
Seihorst, M. V. 100, 200
Seisor, R. E. 110, 720
Sen, S. R. 100, 710
Sexton, D. E. 110, 530
Seyffer, L. R., V 110, 320
Shabon, A. M. 120, 410
Shakhmundes, L. 130, 210
Shapiro, K. H. 110, 700
Sharpe, A. 110, 010
Shaughnessy, D. F. 110, 120
Shaw, B. D. 120, 940
Shaw, C. M. 110, 420

Shaw, L. H. 100, 500
Shaw, R. P. 120, 840
Sheehan, J. B. 110, 420
Sheehan, R. J. 130, 210
Shilling, J. D. 110, 210
Shima, Y. 110, 630
Shin, P. Y. H. 110, 310
Shirima, M. 100, 940
Shoemaker, R. 100, 110
Shunk, E. S. 110, 410
Sid Ahmed, A. 110, 120
Siggel, E. W. 120, 410
Silva, J. E. 110, 420
Silva, J. J. M. d. 110, 130
Silvany, A. J. 110, 940
Silver, I. A. 130, 210
Simon, J. 120, 440
Simons, V. D. 120, 630
Sinai, A. 130, 310
Singer, J. J. 130, 630
Singer, M. 110, 120
Singleton, C. B. 120, 110
Sinha, J. N. 110, 840
Sinha, R. 100, 710
Sirkin, G. 100, 310
Sirvaitis, L. 130, 310
Siu, A. K. 110, 210
Siwingwa, N. R. 110
Skirvin, J. P. 130, 220
Slifman, L. 130, 310
Slotkin, R. L. 120, 020
Small, A. H. 110, 420
Small, L. E. 120, 710
Smith, B. J. 110, 050
Smith, B. W. 130, 210
Smith, D. K. 120, 440
Smith, E. H. 110, 120
Smith, E. K. 110, 940
Smith, G. W. 110, 420
Smith, L. 120, 720
Smitka, M. J. 110, 430
Snipes, F. E., Jr 120, 720
Snodgrass, D. R. 120, 800
Snyder, R. M. 130, 520
Snyder, W. W. 110, 320
Soberon, O. M. 110, 320
Sobrecarey, I. A. 110, 510
Sokol, J. B. 110, 320
Sokoloff, J. J. 110, 120
Sokolov, L. 130, 520
Solar, D. 120, 420
Solecki, J. J. 110, 720
Soligo, R. 120, 020
Solomon, H. S. 110, 820
Solomon, M. J. 110, 220
Sommers, A. T. 130, 110
South, D. W. 110, 940
Spencer, D. L. 110, 620
Spraakman, G. P. 110, 530
Springer, W. L. 130, 320
Spulber, N. 110, 050
Staab, M. 100, 900
Staats, C. R. 110, 940
Staebler, N. 110, 440
Staelin, C. P. 110, 420
Stageberg, S. P. 110, 430
Staig, M. S. 110, 120
Stalleerts, R. 110, 210
Stallings, K. B. 130, 310
Stam, J. M. 110, 320
Standish, T. K. 110, 940
Stark, J. I. 130, 000
Stark, O. 100, 820
StaRomana, L. L., III 120, 420
Stauffer, R. V. 120, 930
Steel, W. F. 120, 630
Steen, D. R. 110, 710
Stein, M. M. 100, 210
Steindel, C. 130, 300
Steinman, G. 130, 840
Stekler, H. O. 130, 600
Sterglanopoulos, P. G. 120, 220
Sterling, A. G. 110, 520
Stern, E. 120, 440
Stern, J. J. 120, 420
Sternlight, D. 130, 720
Stettner, W. F. 110, 320
Stevens, K. C. 130, 820
Stewart, B. D. 130, 220
Stewart, C. T. 110, 810
Stewart, D. E. 110, 520
Stewart, J. R. 110, 410
Stifel, L. D. 100, 440
Stokely, H. 130, 520
Stokes, C. J. 120, 930
Stokes, H. K., Jr 130
Stokes, W. E. D. 130, 430
Stoleru, L. 100, 910
Stolnitz, G. J. 120, 840
Stolper, W. F. 110, 420
Stone, R. 110, 220
Stonier, C. E. 120, 930
Strangways, R. 130, 720
Strasser, E. M. 110, 120
Strassmann, W. P. 110, 930
Strazheim, D. H. 130, 000
Street, J. H. 110, 400
Streeten, P. P. 120, 440
Strout, A. M. 110, 700
Stryker, J. D. 120, 710
Suarez-Mier, M. 130, 320
Subramaniam, I. A. 100, 800
Sun, C. 110, 130
Suriyakumaran, C. 110, 420
Suver, C. W. 130, 210
Swan, N. M. 130, 820
Swasono, Y. 120, 810
Swenson, B. D. 110, 940
Swift, T. K. 130, 620
Syrquin, M. 110, 020
Szal, R. J. 110, 120
Szekeres, S. 110, 520
Tacke, M. 100, 800
Taguchi, Y. 120, 040
Taira, K. 120, 820
Takagi, Y. 120, 440
Takatsu, S. 110, 210
Takayama, T. 110, 210
Talbot, N. H. 100, 000
Taliaferro, R. T. 130, 310
Talley, R. J. 130, 310
Tallman, E. W. 130
Talukder, R. K. 110, 730
Tan, H. 100, 400
Tanaka, N. 110, 310
Tang, A. M. 110, 710
Tangri, S. S. 110, 120
Tansky, L. 120, 410
Tansky, R. E. 130, 210
Tantazzi, A. 130, 020
Tanzer, M. D. 110, 720
Tatom, J. A. 130, 310
Taurand, F. 130, 210
Taylor, C. R. 100, 320
Taylor, J. R. 120, 710
Taylor, L. 110, 120
Tebbutt, A. R. 130, 220
Teitel, S. 100, 600
Tella, D. M. 110, 050
Tellew, F. H. 110, 310
Tendler, J. 120, 440
Teplin, A. M. 130
Terrell, K. D. 120, 820
Tesfatsion, L. 110, 210
Tesfaye, S. B. 110, 710
Thirlwall, A. P. 110, 430
Thirsk, W. R. 110, 320
Thisen, J. K. 110, 310
Thoman, C. B. 110, 030
Thomas, A. R. 130, 520
Thomas, D. B. 120, 620
Thomas, M. D. 110, 940
Thompson, S. J. 110, 940
Thorbecke, E. 110, 420
Thorndike, A. B. 110, 210
Thorne, A. P. 110, 320
Thornton, J. 110, 050
Throup, M. A. 110, 130
Thunberg, R. 130, 300
Thuyst, P. V. 120, 210
Tidrick, G. M. 120, 420
Tietz, L. O. 130, 520
Tillman, R. 120, 630
Timberg, T. A. 120
Tinbergen, J. 110, 820
Tinsley, J. F. 110, 120
Tirmazi, S. H. 110, 210
Titus, V. K. 110, 320
Tobal, C. F. 110, 720
Todaro, M. P. 120, 800
Tonak, E. A. 120, 210
Tongue, W. W. 130, 520
Torres, R. 110, 220
Tosi, D. 110, 420
Townsend, H. 130, 210
Trak, A. 120, 030
Tran, D. T. 100, 400
Traywick, L. E. 130, 940
Trebat, T. J. 120, 430
Trejo-Reyes, S. 110, 430
Triantis, S. G. 110, 420
Trosper, R. L. 110, 940
Troub, R. M. 100, 400
Trubac, E. R. 130, 620
Trutko, J. W. 100, 500
Tsantis, A. C. 100, 810
Tsikata, T. M. 110, 120
Tsuru, S. 110, 910
Tsushima, T. 110, 310
Tucek, D. G. 130, 210
Turner, P. P. 130, 430
Twum-Barimah, D. N. 110, 320
Tyler, W. G. 110, 420
Udall, A. T. 110, 820
Uffner, M. S. 130, 520
Ullian, F. S. 110, 220
Ulmer, M. J. 110, 320
Uzawa, H. 100, 020
Vaccara, B. 130, 630
Valles, J. 100, 000
Van Ardenne, C. H. 130, 110
Van Buer, F. D. 110, 320
Van Cook, C. F. 120, 440
Van Der Heide, E. M. 110, 320
Van Der Hoeven, R. E. 110
Vanderhoff, J. H. 130, 310
Van Der Pluijm, T. W. 110, 710
Van de Wetering, H. 110, 000
Van Duijn, J. J. 130, 940
Vanegas F, M. 110, 710
Van Geel, M. 130, 310
Varley, J. W. 110, 440
Vattar, R. H. 130, 520
Vaut, G. A. 100, 700
Vermeeren, J. G. A. 130
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Vignola, L. 110, 630
Viksnins, G. J. 110, 120
Vinje, D. L. 100, 400
Virata, C. E. A. 100, 300
Vivo, G. H. 110, 500
Vlachos, P. G. 110, 210
Volis, L. R. 130, 200
Voloudakis, E. 120, 310
Von Reiche, L. J. 110, 440
Wachtel, P. A. 130, 300
Wadstad, O. G. 110, 210
Wagner, F. E. 100, 800
Wallace, A. 130, 010
Wallace, F. H. 110, 410
Wallace, J. P., III 110, 210
Walter, C. M. 100, 200
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Wang, H. 110
Wang, M. M. 130, 200
Wang, N. T. 120, 440
Wang, T. 120, 210
Warin, M. H. 120, 410
Wasow, B. M. 110, 400
Wasserfallen, W. 130, 210
Wasserman, K. 130, 930
Wessink, D. 120, 400
Waterston, A. 100, 110
Watkins, R. J. 120, 630
Watkins, T. H. 130, 110
Watteyne, A. L. 110, 030
Wattlsworth, M. 110, 320
Waughray, V. 120, 430
Weaver, F. S. 120, 040
Weaver, J. A. 110, 050
Weaver, J. E. 100, 400
Weaver, J. H. 100, 400
Weaver, R. D. 110, 210
Webb, R. C. 110, 820
Webber, C. M. 100, 500
Weckstein, R. 110, 030
Wellenmann, J. 130, 300
Welmer, D. P. 130, 500
Weiss, B. H. 110, 310
Weiss, J. S. 110, 910
Weiss, S. F. 110, 930
Weissskoff, R. 120, 630
Weller, B. R. 130, 210
Weller, L. O. 130, 510
Wellisz, S. 110, 020
Wells, J. C. 110, 120
Welsch, J. 110, 620
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Wende, R. W. 130, 210
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Westley, J. R. 120, 040
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Wheat, L. F. 110, 940
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Wieczorek, C. A. 130, 210
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Wilford, W. T. 100, 430
Will, R. E. 110, 820
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Williams, B. L. 130, 520
Williams, F. E. 120, 940
Williams, R. J. 130, 310
Williams, R. M. 130, 110
Willmore, L. N. 120, 420
Wills, I. R. 120, 710
Wills, J. H. 100, 300
Wilson, G. W. 120, 610
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Cooper, T. W. 220, 320
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Cordo, S. F. 200, 030
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Daub, M. A. 210, 610
Daughety, A. F. 210, 610
Daule, T. V. 210, 850
Davies, Y. F. 220, 930
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Davis, R. W. 210, 620
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Harvey, G. W. 210, 920
Harwayne, F. 210, 220
Hasan, I. 210, 400
Hastings, D. C. 220, 510
Hatfield, C. H. 210, 530
Hausgaard, O. 220, 610
Hausman, J. A. 210, 320
Havenner, A. M. 210, 310
Haworth, J. G. 200, 820
Hay, J. W. 200, 800
Hayashi, F. 210, 310
Hayashi, M. 210, 410
Hazlia, M. 210, 630
Heckman, J. J. 210, 800
Heineke, J. M. 210, 020
Henning, J. A. 210, 220
Herzig-Marx, C. 210, 310
Hesseiman, L. 210, 630
Hester, D. D. 210, 310
Hibbs, D. A. 210, 830
Higs, S. 210, 320
Hildreth, C. 210, 020
Hilgert, R. J. 210, 630
Hill, J. 210, 610
Hirschberg, J. G. 210, 630
Ho, A. K. 210, 410
Hochheimer, F. L. 210, 710
Hodges, D. J. 210, 020
Hodgson, T. A. 220, 210
Hoffard, D. G. 210
Hoffenberg, M. 220, 510
Hoffman, A. E. 210, 520
Hoffman, D. L. 210, 430
Hoggatt, A. C. 210, 610
Holahan, W. 200, 600
Holley, D. W. 210, 900
Holt, J. T. 210, 620
Holtberg, P. D. 210, 010
Honda, Y. 210, 310
Honohan, P. 210, 310
Hooper, J. W. 210, 520
Horner, S. M. 210, 620
Horowitz, A. R. 210, 320
Horowitz, C. M. 220, 830
Houser, W. 220, 210
Howard, R. T. 210, 720
Howe, E. C. 210, 130
Howe, H. J. 210, 130
Hsia, k. T. 210, 630
Hsiao, C. 210, 100
Hsiao, M. W. 210, 020
Hsu, H. C. 210
Hu, T. 210, 910
Huang, C. J. 210, 020
Huang, L. 210, 920
Huang, T. 210, 110
Hudson, E. A. 210, 110
Huffnagle, J. D. 210, 020
Hughey, V. A. 210, 840
Hulett, D. T. 210, 130
Hulten, C. R. 220, 320
Hunt, P. T., Jr 210, 130
Hunter, K. R. 210, 220
Huq, S. 200
Hurd, D. R. 210, 310
Hurdle, G. J. 210, 610
Hussain, M. 210, 020
Hutchins, S. A. 210, 620
Huth, W. L. 200, 600
Hwa, E. 210, 060
Hylleberg, S. 210, 000
Hymans, S. H. 210, 130
Ibrahim, I. A. S. 210, 020
Ilardi, G. 210, 720
Ireland, M. E. 210, 130
Irvine, I. J. 210, 850
Ishikawa, M. 210, 820
Isola, R. T. 210, 130
Ivory, P. D. 210, 500
Jackson, J. R. 210, 720
Jackson, S. M. 210, 910
Jacob, C. J. 220
Jaffe, S. A. 220, 210
Jahnke, W. 210, 130
James, R. C. 200, 100
Jassim, F. I. 210, 110
Jazzi, G. 200, 100
Jedel, P. H. 210, 010
Jensen, B. 210, 020
Jensen, L. G. A. 210, A00
Jeong, D. 210, 300
Jeong, K. 210, 410
Jewett, F. I. 210, 020
Jewett, R. B. 220, 010
Jhaveri, D. R. 200, 100
Johnson, E. R. 220, 720
Johnson, G. D. 210, 940
Johnson, K. N. 210, 020
Johnson, L. W. 210, 920
Johnson, S. P. 210, 130
Johnson, T. 210, 810
Johnson, T. P. 210, 850
Johnston, J. 210
Jones, J. F. 210, 130
Jordan, J. 210, 710
Jordan, J. M. 200, 630
Jorgenson, D. W. 210, 020
Joskow, J. 200, 610
Joun, R. Y. P. 210, 110
Ju, S. 210, 440
Jung, W. S. 200, 300
Just, R. E. 210, 700
Juster, F. T. 220, 920
Kahane, P. R. 210, 840
Kalaba, R. E. 210, 110
Kalaitzis, V. C. 210, 530
Kalcic, B. W. 200, 800
Kalish, C. B. 220, 810
Kalick, S. 220, 630
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Kane, J. J. 210, 920
Kang, H. 210, 020
Kapil, D. P. 200, 020
Karns, J. M. L. 210, 940
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Kasten, R. A. 210, 910
Katz, A. J. 200, 900
Katz, P. C. 210, 530
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Kavanaugh, D. C. 210, 310
Kawasaki, S. 210, 010
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Keeler, J. 210, 610
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Keller, W. J. 210, 320
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Kendrick, D. A. 210, 110
Keng, C. W. K. 210, 130
Kenkel, J. L. 210, 130
Kennedy, S. D. 210, 900
Kennes, W. E. M. 210, 710
Kestle, W. R. 200, 630
Kettner, G. A. 210, 850
Kexel, D. T. 210, 940
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Kiefer, N. M. 200, 800
Kim, C. 210, 810
Kim, H. J. 210, 020
Kim, H. Y. 210, 130
Kim, J. 210, 420
Kim, U. 210, 110
Kim, Y. 210, 410
Kimbell, L. J. 210, 130
Kinal, T. 210, 520
Kindahl, J. K. 200, 020
King, A. E. 210, 050
King, C. J. 210
Kinney, D. E. 210, 320
Kinoshita, S. 210, 630
Kirchgaessner, G. 210, 320
Klatt, H. 220, 210
Klein, L. R. 210, 130
Klein, R. A. 210, 320
Kleykamp, D. 210, 310
Klosk, T. 210, 130
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Koenker, R. 210, 610
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Komijani, A. 210, 430
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Kopp, R. J. 210, 600
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Kraft, G. A. 210, 020
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Krieger, S. C. 210, 310
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Kuh, E. 210, 130
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Kuhn, H. W. 210, 020
Kuiper, J. 210, 130
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Kwak, N. K. 210
Kwak, S. 200, 400
Kymn, K. O. 210, 720
Labys, W. C. 210, 720
Ladd, G. W. 210, 530
LaFrance, J. T. 210, 720
Lahiri, K. 210, 010
Lai, L. K. 200, 500
Lai, S. H. 200, 300
Laity, J. K. 210, 020
Lancaster, M. A. 210, 720
Lane, W. F. 220
Larsen, K. E. 210, 720
Larsen, M. W. 210, 710
Larson, G. P. 200, 800
Larson, J. C. 210, 300
Lasaga, M. 210, 410
Lau, L. J. 210, 020
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Lay, R. N. 210, 440
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Le, S. V. 210
Leabo, D. A. 210, 610
Leach, N. L. 220, 720
Leamer, E. E. 210, 400
Lebergott, S. 220, 040
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Lee, J. 210, 700
Lee, J. W. 210, 400
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Lee, K. K. 210, 630
Lee, L. 210, 800
Lee, T. H. 210, 920
Lee, W. B. 210, 410
Leidy, J. 210, 610
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Leontief, W. 210, 020
Leslie, G. M. 220, 120
L'Esperance, W. L. 210, 940
Levine, R. A. 220, 510
Levy, D. M. 210, 030
Levy, J. 210, 620
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Liang, K. 200, 100
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Liliard, L. A. 210, 820
Lin, A. 210, 310
Lin, A. K. 200, 300
Lin, K. 210, 720
Lin, P. C. 210, 020
Lin, T. 210, 310
Lin, W. T. 200
Lininger, C. A. 220, 910
Lissner, W. 210, 840
Litterman, M. A. 210
Liu, B. 210, 720
Liu, T. H. 210, 100
Livesey, D. A. 210, 930
Lo, A. W. 210, 310
Loeb, P. D. 210, 020
Logan, R. F. 210, 310
Long, N. B. 220, 050
Long, S. B. 220, A00
Longley, W. W. 210, 540
Los, C. A. 210, 310
Lott, W. F. 210, 010
Lowenstein, H. 220, 830
Lu, Y. 210, 620
Luan, D. C. 200, 310
Ludolph, C. M. 210, 410
Lund, D. C. 220, 430
Lutich, K. J. 210, 220
Lutz, J. J. 210, 130
Lyman, R. A. 210, 020
Lyons, E. T. 210
Ma, Z. M. 210
MacKinnon, J. G. 210, 010
MacRae, E. C. 200, 720
Maddala, G. S. 210, 030
Madduri, S. 200, 720
Maffei, V. L. 210, 310
Maguire, J. C. 210, 020
Mairesse, J. 200, 600
Malabarba, D. 210, 220
Malcomson, J. M. 210, 020
Maley, L. A. 200, 540
Malleia, P. 210, 610
Manage, N. D. 210, 430
Mann, J. S. 210, 020
Manning, R. E. 210, 130
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Manuel, E. H. 210, 600
Marsavall, A. 210, 310
Marcotulli, R. J. 200, 500
Margolin, E. R. 210, 530
Margolis, M. S. 210, 310
Mariano, R. S. 210, 130
Mark, J. A. 220, 620
Marking, M. P. 210, 520
Marks, B. J. 210, 030
Marks, S. G. 210, 610
Marks, T. H. 210, 610
Marquez, J. 210, 430
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Marshall, G. L. 210, 120
Martin, J. C. 210, 100
Martin, L. F. 220, 940
Martin, M. E. 220, 820
Masch, V. A. 210, 520
Masters, M. M. M. 210, 010
Mathieson, R. 210, 420
Mattern, V. A. 210, 310
Mauer, W. A. 200, 510
May, D. F. 210, 120
Mayer, D. L. 210
Mayes, D. G. 200, 420
McAllister, H. E. 210, 220
McCracken, M. C. 210, 130
McDonald, J. 210, 130
McDonald, J. B. 210, 020
McDonald, R. J. 220, 020
McElroy, F. W. 210, 610
McElwain, A. M. 210, 610
McFadden, D. 210, 020
McGuire, T. W. 210, 020
McKean, J. R. 200, 720
McKee, J. R. 210, 430
McLaren, K. R. 210, 020
McMeekin, G. C. 210, 320
McNown, R. F. 210, 130
Meiners, M. R. 220, 900
Meisner, J. F. 210, 020
Meissner, W. 210
Meiberg, W. F. 210, 520
Merkies, A. 210, 130
Michel, R. C. 210, 910
Michelson, S. 210, 800
Miller, A. C. 210, 620
Miller, E. A. 210, 130
Miller, G. L. 210, 130
Miller, H. P. 220, 840
Miller, H. S. 220, 920
Miller, R. E. 200, 610
Miller, R. E. 210, 940
Miller, T. I. 210, 310
Min, A. 210, 020
Mitchell, T. M. 210, 430
Miyabe, J. 210, 120
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Moffet, D. 210, 520
Moffitt, L. J. 210, 700
Molander, A. I. 210, 130
Monadjemi, M. S. 210, 310
Monroe, C. J. 210, 630
Monroe, S. A. 210, 620
Montmarquette, C. 210, 440
Moody, C. E. 210, 020
Moody, S. L. 210
Moses, D. M. 220, 630
Morales, J. 210, 110
Morawetz, J. H. 220, 130
Morey, M. J. 210, 020
Morgan, J. N. 220, 920
Morian, T. H. 210, 940
Morrow, H. G. 220, 830
Morrow, J. F., Jr 210, 610
Morse, L. B. 220, 910
Morton, A. S. 210, 710
Moscoso, F. J. 210, 320
Moszer, M. 210, 130
Moulton, E. S. 220, 430
Mount, T. D. 210, 710
Mourgos, S. L. 210, 110
Muellbauer, J. N. 210, 920
Mulherir, J. H., III 210, 020
Mundell, C. L. 210, 020
Munduch, G. 210, 130
Murasko, J. E. 210, 520
Murphy, E. H. 220, 520
Murphy, J. L. 210, 720
Murty, P. S. K. 220, 630
Musacchio, R. A. 210, 610
Mustafa, A. A. 220, 020
Muttardy, A. 210, 620
Myers, R. J. 220, 810
Myers, S. L., Jr 210, 820
Nahata, B. L. 210, 610
Nakamura, A. O. 200, 800
Nakamura, M. 210, 020
Narasimham, G. V. L. 210, 110
Narayanan, R. 210, 720
Nargund, N. K. 210, 300
Naseeh, A. 210, 310
Natrella, V. 220, 520
Naylor, T. H. 210, 500
Naz, M. A. H. 220, 110
Nazoe, S. E. 210
Nelson, C. R. 210, 310
Nelson, F. D. 210, 000
Neri, J. A. 210, 720
Nerlove, M. L. 210, 840
Nguyen, H. D. 210, 700
Nguyen, H. V. 210, 310
Niekerk, D. C. 210, 310
Niemeyer, E. V. 210, 720
NiJhowne, S. 210, 630
Noren, P. B. R. 222, 420
Norwood, J. L. 200, 800
Nosal, C. 210, 020
Nothaft, F. E. 210, 810
Nozicka, G. J. 220, 210
Ntalaja, K. 210, 130
O'Brien, R. C. 200, 530
Ohidieck, K. J. 210, 500
Okun, B. 210, 110
O'Leary, E. J. 210, 610
Olior, W. G. 210, 410
Olson, J. A. 210, 940
Ono, M. 220, 910
Opaluch, J. J. 210, 720
Orkand, D. S. 210, 510
Ortego, J. H. 200, 600
Osayimwese, I. 210, 630
Osborne, H. D. 200, 100
Osman, J. W. 210, 320
Ostrosky, A. L. 210, 840
Ott, D. A. 210, 020
Ovadovitz, A. 200, 840
Pabst, W. R. 210, 610
Pacheco, P. L. 210, 130
Pachon, A. 220, 930
Pagan, A. R. 210, 130
Palk, S. 210, 720
Palma, P. A. 210, 430
Panerall, R. B. 210, 920
Papadopoulos, K. D. 210, 940
Papapanos, A. 210, 520
Paranavitana, C. 210, 020
Paris, Q. 210, 110
Park, A. S. K. 210, 620
Park, C. 210, 310
Park, H. Y. 210, 940
Park, J. W. 210, 310
Park, S. 210, 110
Park, S. 210, 020
Parker, R. P. 220, 610
Parr, J. O. 210, 520
Parris, H. L., Jr 200, 800
Pascal, N. S. 210, 020
Patel, R. C. 210, 100
Peck, J. M. 210, 130
Peden, E. A. 210, 910
Penson, J. B., Jr 210
Perdue, R. K. 210, 520
Peri, L. J. 210, 820
Perryman, M. R. 210, 310
Peskin, H. M. 220, 720
Peskin, J. K. 220, 910
Peters, J. V. 210, 520
Peters, R. K. 210, 710
Petramas, A. A. 210, 820
Petrick, K. A. 220, 610
Pfannestiel, M. 210, 020
Pfersich, H. E. 210
Picado Horta, C. A. 210, 520
Pierce, D. A. 210, 130
Pilcher, G. W. 210, 030
Pirog, R. L. 210, 320
Pitzer, J. S. 220, 050
Plant, M. W. 210, 820
Plosser, C. I. 210, 310
Poirier, D. J. 210, 000

Poitras, G. 210, 520
Pomer, M. I. 210, 800
Poon, N. 210, 410
Popowicz, G. A. 210, 940
Popper, R. D. 210, 510
Porslus, P. 210, 310
Portillo-Campbell, J. H. 210, 130
Poulios, N. S. 210, 130
Powell, A. A. L. 210, 110
Powell, J. L. 210, 430
Premaritut, R. 210, 320
Preston, E. 210, 110
Proctor, E. W. 220, 050
Proenza, F. J. 210, 700
Promboin, R. L. 210, 320
Proudley, G. E. 220, 610
Psenicka, C. O. 210, 930
Pyo, H. K. 210, 300
Quandt, R. E. 210, 020
Radecki, L. J. 210, 310
Radner, D. B. 220, 000
Raduchel, W. J. 210, 610
Rahimian, N. 210, 420
Raimondi, M. J. 210, 500
Raj, B. 210, 020
Ramachandran, V. 210, 610
Ramenofsky, S. D. 210, 220
Ramsey, J. B. 210, 020
Rao, P. M. 210, 130
Rao, S. A. 210, 420
Rao, V. 210, 720
Rao, V. Y. 210, 220
Raphael, L. 210, 630
Rardin, J. D. 210, 720
Raynsford, R. W. 220, 210
Reclam, M. 210, 430
Reece, W. S. 200, 610
Reedy, D. E. 210, 610
Regev, U. 210, 720
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Reiling, E. A. 210, 710
Reiser, B. S. 220, 410
Reiss, P. C. 210, 800
Renfro, C. G. 210, 130
Reos, O. A. 210, 720
Resek, R. W. 210, 130
Revankar, N. S. 210, 220
Reznek, A. P. 210, 720
Rhodes, G. F., Jr 210, 020
Riall, B. W. 210, 130
Rice, G. R. 210, 810
Rich, E. H. 210, 620
Richards, P. 210, 720
Richter, B. J. 210, 913
Richter, M. K. 210, 020
Riddell, W. C. 210, 830
Rider, K. L. 210, 520
Rippe, R. D. 210, 130
Rivera, M. J. 200, 100
Rivera, R. D., Jr 210
Roberts, D. C. 210, 630
Roberts, H. V. 210, 500
Robins, P. K. 200, 810
Robinson, P. B. 210, 610
Roddy, D. J. 210, 130
Rodekohr, M. 210, 850
Rodgers, L. J. 210, 850
Rohr, R. J. 210, 020
Rojanasakul, P. 210, 400
Rojas, L. H. 210, 520
Rosenberg, S. 210, A00
Rosett, R. N. 210, 920
Rossana, R. J. 210, 410
Roth, J. A. 210
Rothenberg, T. J. 210, 020
Rothrock, T. P. 210, 610
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Rowe, R. D. 210, 720
Rowley, J. C. R. 210, 130
Rowse, J. G. 210, 610
Rozek, R. P. 210, 610
Rufatt, O. A. 210, 130
Ruggles, N. D. 220, 320
Ruggles, R. 220, 320
Rule, W. T. 210, 600
Russo, W. J., Jr 220, 720
Ruud, P. A. 210, 810
Ryan, D. A. 210, 800
Sacha, W. S. 220, 010
Saghafi, M. M. 210, 410
Saito, M. 210, 130
Sakellis, M. 200, 320
Salazar, C. B. 210, 520
Sale, T. S., III 220, 520
Saleh, A. A. 210, 710
Salomon, M. A. 210, 320
Saltzman, S. 210, 940
Samuelson, L. W. 210, 130
Samur, C. E. 210, 130
Sant, D. T. 210, 020
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Sarkar, A. K. 210
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Sassone, P. G. 210, 910
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Savitt, J. H. 210, 940
Sawyer, V. 220, 920
Schaake, R. A. 210, 310
Schianchi, A. 210, 110
Schieren, G. A. 210, 110
Schilling, E. G. 210, 220
Schleicher, S. P. 210, 430
Schmidt, J. R. 210, 310
Schmidt, P. J. 210, 000
Schmidt, S. S. 210, 610
Schoech, P. E. 200, 600
Schoepfle, G. K. 210, 420
Schrank, W. E. 210, 720
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Scott, D. P. 210, 220
Scott, R. C. 210, 020
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Seidel, M. R. 210, 720
Seldon, B. J. 210, 310
Sellekaerts, B. H. 210
Selwyn, L. L. 210, 610
Semudram, M. 210, 430
Senger, D. J. 200, 100
Serot, D. E. 210, 720
Seshu, C. R. 210, 110
Sevier, M. A. 210, 130
Sewell, W. P. 210, 610
Shameer, A. E. 210, 630
Shapiro, H. T. 200, 300
Shapiro, S. J. 210, 320
Sharefkin, M. 210, 720
Shaw, W. F. 210, 130
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Sheftel, H. B. 200, 630
Shelfer, V. J. 220, 820
Shellhammer, K. L. 210, 940
Shen, F. C. 210, 110
Sherr, L. A. 210, 510
Shiau, L. 210, 310
Shukla, V. S. 200, 100
Sicklea, R. C. 210, 620
Siddiqi, Y. M. 220, 630
Sidhu, N. D. 210, 630
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Siegel, I. H. 210, 110
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Silver, J. L. 210, 820
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Simes, R. M. 210, 310
Simon, N. W. 220, 000
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Sims, C. A. 210, 130
Singamsetti, R. 210, 020
Singleton, K. J. 210, 310
Sitzer, S. B. 210, 720
Sivard, R. L. 220, 320
Skoog, G. R. 210, 130
Skorburg, J. W. 210, 920
Skulmis, V. H. 200, 930
Slatin, B. 220, 130
Sleemi, F. R. 210, 220
Slottje, D. J. 210, 610
Small, E. M. 210, 810
Small, S. S. 220, 810
Smith, B. R. 210, 520
Smith, D. A. 210
Smith, D. A. 210, 020
Smith, J. D. 200, 920
Smith, J. F. 210, 310
Smith, J. L. 210, 720
Smith, M. C. 210, 410
Smith, M. W. 210, 000
Smith, P. M. 210, 130
Smith, R. P. 210, 320
Smith, S. J. 210, 310
Smith, V. K. 210, 720
Snead, J. D. 210, 220
Snoke, D. D. 210, 720
Snow, M. S. 210, 610
Snyder, T. R., Jr 210, 940
Sobol, M. G. 220, 810
Sohn, H. K. 210, 900
Sohn, I. M. 210, 720
Soliman, M. A. 210, 850
Solomon, H. 210, 020
Sommers, P. M. 210, 840
Somwaru, A. L. 200, 700
Sowa, E. N. K. 210, 310
Sowey, E. R. 210, 130
Spady, R. H. 210, 610
Spahn, P. B. 210, 320
Spanos, A. 210, 310
Spencer, D. E. 210, 310
Spencer, J. E. 210, 310
Spilsbury, R. G. 210, 840
Spinard, W. F. 210, 310
Spitzer, J. J. 210, 320
Spivey, W. A. 210, 220
Springer, J. Y. 210, 130
Sproul, K. H. 210, 020
Squitieri, R. L. 210, 010
Stadelman, D. 210, 720
Stafford, J. R. 210, 310
Stapleton, D. C. 210, 810
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Stavy, M. 200, 540
Stecher, E. L. 210, 020
Steinike, G. C. 210, 130
Steinkamp, S. W. 210
Steinnes, D. N. 210, 930
Sterbenz, F. P. 210, 130
Stern, G. 210, 720
Stern, S. N. 210, 320
Stewart, W. L. 220, 810
Stipec, M. R. 200, 020
Stobbe, A. 220, 010
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Stockton, J. R. 220, 130
Stoker, T. M. 210, 220
Stokes, E. B. 200, 300
Stolen, J. D. 210, 000
Story, R. E. 210
Strack, C. W. 210, 940
Strand, J. L. 210, 610
Strauss, J. 210, 120
Strauss, S. J. 210, 010
Strotz, R. H. 210, 000
Stuligross, J. D. 210
Su, T. T. 210, 020
Suh, D. E. 210
Suits, D. B. 210, 130
Summers, R. 210, 220
Sung, C. H. 210
Suoniemi, I. V. J. 210, 020
Swaim, R. H. 210, 810
Swanson, J. A. 210, 520
Swartz, S. T. 210, 820
Sylvester, R. A. 210, 640
Takenaka, O. 210, 620
Tam, P. C. K. 220
Tan, J. K. 210, 310
Tate, J. M. 210, 610
Tauchen, G. 200
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Taylor, T. N. 210, 720
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Teigen, L. D. 210, 710
Teisar, L. G. 210, 610
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Terza, J. V. 210, 800
Tessmer, R. G., Jr 210, 620
Thabet, B. 210, 110
Thangiah, S. G. 200, 210
Theil, H. 210, 920
Theodore, C. A. 220, 510
Therrio, C. J. 220, 910
Thibodeau, T. G. 210, 930
Thomas, R. W. 210, 130
Thomas, S. J. 210, 630
Thomassen, H. 210, 320
Thompson, G. E. 210, 220
Thompson, R. G. 210, 720
Thompson, W. F. 210, 130
Thomson, M. H. 210, 020
Thore, S. A. 210, 050
Throsby, C. D. 210, 710
Thursby, J. G. 210, 810
Tice, H. S. 220, 010
Tiller, R. B. 220, 820
Tonkin, R. S. 210, 010
Toporovsky, R. H. 200, 520
Tountas, S. D. 210, 930
Townsend, M. G. 210, 410
Train, K. 210, 610
Traxler, H. G. 220, 850
Tretheway, M. W. 210, 630
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Trimnell, F. O. 210, 720
Trinki, F. H. 210, 020
Trivedi, P. K. 200, 130
Trost, R. P. 210, 020
Troy, W. F. 220, 810
Tsao, I. T. 220
Tsao, J. T. H. 210, 400
Tseng, K. 200, 130
Tu, Y. 210, 020
Tuan, C. 210, 110
Tulkens, H. G. 210, 320
Tung, C. 210, 940
Tung, S. 210, 020
Tyers, R. 210, 420
Tyree, K. R. 200, 600
Tyrrell, T. J. 210, 900
Tyson, H. L., III 210, 810
Tzon-Biau, L. 210, 400
Ueno, H. 210, 110
Unger, S. G. 210, 710
Upcher, M. R. 210, 310
Urbisais, H. L. 210, 220
Ursprung, H. 210, 430
Van Boven, H. J. 210, 520
Vandasie, W. 210, 810
Vandenbrink, D. C. 210, 930
Van Der Knoop, H. S. 210, 310
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Van Der Voort, A. B. 220, 530
Van Dyke, D. T. 210, 940
Van Llerop, J. 210, 930
Van Peetersen, A. 210, 130
Van Peski, N. G. 220, 310
Van Rompuy, P. 210, 820
Varley, S. M. 210, 130
Venyah, L. K. 220, 820
Verdoorn, P. J. 210, 410
Vermot-Desroches, B. 210, 120
Verstraete, J. 210, 020
Vest, J. F. 220, 210
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Villavicencio, J. R. 210, 320
Villeta-Trigo, J. A. 210, 120
Villwock, K. C. 210, 610
Vinci, S. 210
Vinod, H. D. 210, 600
Vo, D. H. 210, 710
Von Hohenbalken, B. 210, 020
Wadycki, W. 210, 840
Waelbroeck, J. L. 210
Wagner, J. P. 210, 700
Wago, H. 210, 130
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Walker, D. A. 210, 310
Walker, M. A. 220, 040
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Warren, H. E. 210, 600
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Watkins, W. S. 200, 500
Watson, R. A. 210, 940
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Weatherby, J. L. 200, 940
Weatherwax, R. K. 210
Webb, P. B. 210, 910
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Weinberg, C. B. 210, 430
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Weiss, M. 210, 720
Weiss, N. E. 210, 930
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Welch, R. O. 220, 120
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Welsch, D. R. 200, 940
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Whiston, W. B. 210, 610
White, K. J. 210, 310
White, L. K. 200
White, T. B. 210, 700
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Wilk, M. B. 210, 220
Wilkinson, M. 210, 020
Wilkinson, R. K. 200, 930
Williams, D. 210, 020
Williams, J. F. 210, 510
Williams, L. J. 210, 130
Williams, M. E. 210, 310
Williams, R. A. 210, 920
Williams, W. H. 210, 220
Willis, C. E. 210, 720
Wilson, A. F. 210, 600
Wilson, D. A. 220, 130
Wilson, N. H. 210, A00
Wiltbank, L. B. 210, 630
Winship, C. 210, 820
Wion, D. A. 220, 310
Wise, D. E. 210, 810
Witt, T. S. 210, 020
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Wolfe, J. R. 210, 800
Wolken, J. D. 210, 610
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Woodham, D. M. 210, 400
Worton, D. A. 220, 110
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Wu, H. 210, 410
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Atkinson, S. S. 310, 020
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Aumann, C. 310, 320
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Avery, R. B. 310, 210
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Babilot, G. 320, 020
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Bagella, M. 300, 100
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Bahiko, E. A. 310, 320
Bailey, M. J. 320, 130
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Ballard, C. L. 320, 820
Ballentine, J. G. 320, 110
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Baqueiro-Cardenas, A. J. 310, 320
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Barry, D. M. 320, 820
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Bartlett, R. L. 310, 220
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Bayard, F. 310, 120
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Benton, R. T. 320, 610
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Bhatia, K. B. 320, 210
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Bijan, M. 310, 430
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Binhammer, H. H. 310, 430
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Bird, R. M. 320, 120
Birdsall, W. C. 320, 020
Bise, R. G. 310, 410
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Blinder, A. S. 320, 130
Blitz, S. 310, 520
Bloch, E. 310, 520
Bloch, E. 320, 420
Blood, D. M. 320, 610
Blumenfeld, A. A. 320, 930
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Boczar, G. E. 310, 520
Bodin, O. 300, 430
Body, D. W. 320, 430
Boelaert, R. 320, 130
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Bomhoff, E. J. 310, 130
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Boschen, J. F. 300
Boskin, M. J. 320, 820
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Bowers, R. D. 310, 130
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Boylan, B. 310, 520
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Brandi, J. E. 320, 210
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Brannen, P. P. 310, 130
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Bray, R. T. 320, 020
Brazer, H. E. 320, 930
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Breimyer, F. S. 310, 320
Brennan, H. G. 320, 010
Brent, R. J. 320
Breton, A. 320, 010
Brice, A. G. 300, 500
Bridges, B. 320, 910
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Brite, G. K. 300, 500
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Brownstein, B. P. 320, 600
Bruce, N. 320, 430
Bruni, F. 310, 430
Brunner, K. 310, 430
Brunner, L. P. 320, 620
Brunner, R. O. 310, 320
Bruno, M. 300, 400
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Bryan, W. R. 310, 130
Bryde, T. J. 310, 210
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Buckley, R. M. 310, 930
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Bucovetsky, S. 320, 020
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Buehler, J. E. 310, 130
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Burns, R. 320
Burrington, L. I. 310, 030
Burstein, M. 310, 610
Buscher, H. S. 310, 210
Butkiewicz, J. L. 300, 040
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Byrne, D. R. 300, 430
Byrns, R. T. 300, 020
Cagan, P. 310, 130
Caikins, S. E. 320, 000
Calmus, T. W. 320, 310
Cambiaso, J. E. 310, 420
Cameron, N. E. 310, 050
Cammarosano, J. R. 320, 930
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Campbell, M. T. 320, 610
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Candilis, W. O. 310, 520
Cannon, W. T. 310, 520
Canaler, D. 320, 720
Canzoneri, M. B. 310, 430
Caplan de Cohen, N. R. 320, 310
Cargill, T. F. 300, 200
Carlino, G. A. 320, 940
Carlos, J. A. 310, 320
Carlson, G. N. 320, 420
Carnevale, J. T. 320, 720
Carpenter, C. C. 310, 000
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Carr, R. A. 310, 440
Carrier, R. E. 320, 110
Carroll, J. J. 320, 910
Cartwright, W. S. 320, 840
Caruso, P. P. 310, 060
Carvalias, J. 320, 930
Casas Pardo, J. 310, 020
Case, K. E. 320, 930
Cassone, A. 320, 930
Cathcart, C. D. 310, 130
Catsambas, T. 320, 130
Catsiapis, G. C. 310, 520
Causa, J. 310, 430
Cell, D. C. 320, 010
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Chacko, K. C. 300, 100
Chall, D. E. 320, 930
Chamberlain, C. A. 310, 210
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Chan, K. C. 310, 520
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Chang, C. F. 320
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Chase, S. B. 310, 320
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Chollet, D. J. 320, 800
Christ, C. F. 300, 210
Christian, J. W. 310, 440
Christiansen, R. E. 310, 520
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Clarke, J. J. 310, 130
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Collins, L. S. 300, 130
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Conklin, C. F. 300, 720
Connolly, R. A. 310, 610
Conrad, W. E. 310, 130
Conway, L. V. 310, 520
Cook, P. K. 310, 610
Cooke, H. J. 300, 310
Cooke, J. P. 320, 020
Cooper, R. W. 310, 020
Cordes, J. J. 320, 920
Corey, G. D. 310, 520
Cornwell, D. W. 310, 520
Costa, E. L. 310, 210
Cottle, R. L. 310, 020
Cottrell, A. F. 320, 610
Courant, P. N. 320, 930
Court, A. T. 310
Covey, F. S. 310, 430
Cox, D. R. 320, 930
Cox, E. B. 310, 520
Cox, J. C. 320, 940
Cox, J. C. 300, 610
Cox, M. W. 310, 430
Craine, R. 300, 200
Creen, J. F. 310, 810
Creswell, J. S. 320, 610
Crews, J. M. 310, 210
Crichfield, D. 310, 020
Crosby, G. E. 310, 130
Cross, R. B. 310, 030
Cross, S. M. 310
Crotsau, J. T. 310, 010
Crotty, J. R. 300, 130
Crouhy-Veyrac, L. L. 300, 400
Cuesta, F. 310, 500
Cunningham, T. J. 310, 410
Cupoli, E. M. 320, 930
Cutler, S. 310, 610
Dalcoff, D. W. 320, 930
Dalton, T. R. 310, 320
Daniel, E. S. 310, 130
Daniel, T. P. 320, 720
D'Antonio, A. 310, 430
Darby, M. R. 300, 430
Darling, P. G. 300, 050
Darr, R. K. 320, 830
Darrat, A. F. 310, 020
David, M. H. 320, 820
Davidson, F. G. 300, 600
Davidson, P. 310, 720
Davidson, P. H. 310, 130
Davidson, P. K. 310, 210
Davie, B. F. 320, 040
Davies, D. G. 320, 010
Davis, A. J. 320, 430
Davis, R. G. 310, 320
Davis, R. R. 310, 430
Dawson, D. A. 320
Dayton, E. C. 310, 320
Deacon, R. T. 320, 720
Deak, N. L. 300
Dean, J. W. 310, 020
Deboer, L. D. 320, 940
Debrecht, D. M. 310, 210
Decaestecker, J. 310, 020
Decou, D. F. 310, 320
de La Vina, L. Y. 300, 800
Deleeuw, F. 300, 200
Delocse, M. J. 310

Del Rey, E. C. 320, 210
Del Rosario, M. F. 310, 320
Demaynadier, A. 300, 400
Dembitz, L. N. 310, 520
Dennis, B. L. 310, 320
Deprano, M. E. 310, 020
Deprince, A. E. 310, 210
Desai, S. A. 320, 110
De Spain, E. 310, 210
Deutsch, A. 320, 420
Dewald, W. G. 310, 130
Dewath, N. V. H. 320, 800
Diamond, A. H. 310, 320
Diamond, D. W. 310, 520
Diamond, P. A. 320, 020
Dickey, J. H. 310, 020
Dickey, S. W. 300
Didine, L. L. 320, 110
Dillaber, P. A. 320, 510
Dilis, R. M. 320, 020
Dilorenzo, T. J. 320, 930
Dince, R. R. 310, 430
Dinkelacker, E. W. 320, 610
Diokno, B. E. 320, 630
Di Tata, J. C. 310, 430
Diulio, E. A. 310, 020
Dobson, L. W. 310, 320
Dodds, J. S. 320, 930
Doessel, D. P. 320, 910
Dominguez, J. R. 310, 520
Dominguez Brio, F. 320, 020
Donahoo, K. K. 310, 430
Donner, A. W. 300
Donovan, C. H. 320, 120
Doral, G. C. 310, 430
Dorsch, A. R. 310, 510
Dorsey, J. W. 320, 810
Dorsey, T. W., Jr 310, 400
Dougan, W. R. 310, 320
Dowling, B. R. 320, 310
Drazen, A. 310, 320
Dreecher, S. 300, 100
Droitsch, R. G. 300, 130
Dubin, E. J. 320, 020
Dubofsky, D. A. 310, 520
Due, J. F. 320, 610
Dugan, D. J. 320, 210
Dukes, J. H. 300, 400
Dunham, C. R. 310, 610
Dunkman, W. E. 310, 430
Dunn, M. L. 320
Dupuis, R. L. 310, 520
Durkin, T. A. 310, 520
Duro, L. E. 310, 130
Dusansky, R. 320, 020
Dutton, D. S. 310, 020
Dwyer, G. P., Jr 310, 130
Dwyer, T. M. 320, 030
Dye, R. F. 320, 910
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Earl, J. F. 320, 420
Earley, J. S. 310, 430
Eaton, R. C. 310, 320
Ebels, D. M. 300, 720
Eberhardt, C. C. L. 310, 820
Eberts, R. W. 320, 940
Ebrill, L. P. 320, 430
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Eden, B. 310, 020
Ederington, L. H. 310, 210
Edwards, A. L. 310, 920
Egan, J. P. 310, 850
Egger, J. B. 310, 030
Eggertsson, T. 300, 800
Eilbott, P. 320, 130
Einsenberg, G. G. 320, 040
Eisenbeis, R. A. 310, 210
Eisenmenger, R. W. 310, 110
Elbatrik, Y. A. 320, 120
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Eliard, C. J. 320, 810
Ellickson, D. L. 320, 520
Elliott, D. S. 320, 210
Elliott, J. W. 310, 130
Ellis, L. V. 310, 320
Ellis, P. A. 310, 430
Elson, R. A. 310, 430
Elston, F. A. 310, 120
Enckell, M. R. 310, 410
England, R. W. 320, 020
Engler-Mansfield, H. 320, 940
Epstein, I. 320, 930
Erb, R. D. 310, 430
Erekson, O. H. 320, 930
Erickson, E. C. 310, 110
Erickson, M. A. 310, 440
Erickson, M. G. 310, 320
Esbitt, M. 310, 520
Escobar, M. 300
Estevez, R. J. 320, 420
Ettin, E. C. 310, 520
Evanoff, D. D. 300, 610
Evans, J. C. 320, 310
Evans, P. D. 310, 210
Exter, J. E. 310, 430
Ezrati, M. J. 310, 130
Fabricant, R. A. 310, 320
Fahey, J. R. 320, 930
Falkowski, D. C. 310, 430
Fand, D. I. 310, 430
Farb, W. E. 320, 130
Farmer, R. E. A. 310, 210
Farnham, P. G. 320, 930
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Farrell, C. H. 310, 010
Fausto, D. 320, 910
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Feinberg, M. S. 300, 400
Feldstein, M. S. 320, 210
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Ferguson, J. D. 310, 130
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Fernandez, R. B. 310, 210
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Fischer, S. 310, 410
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Fishor, C. E. 320, 720
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Fisher, P. 320, 930
Fisher, R. C. 320, 930
Fishman, E. B. 310, 400
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Fletcher, A. L. 320, 420
Floyd, J. E. 310, 430
Flynn, M. A. 320, 800
Foeller, W. H. 320, 820
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Fongemie, C. A. 310, 130
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Ford, W. F. 310, 130
Formuzis, P. A. 310, 000
Forsman, P. J. 300, 020
Fortuna, M. 300, 430
Fortune, P. 310, 320
Fosler, G. D. 320, 310
Foster, M. S. 320, 040
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Fountain, G. A. 310, 320
Fourcans, A. 300, 430
Fox, W. F. 320, 930
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Frank, H. J. 320, 310
Franz, W. W. 320, 310
Fratianni, M. U. 310, 430
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Freedman, C. 310, 430
Frei, R. 310, 430
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Fridjonsson, T. 310, 800
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Friedman, M. 300, 020
Friedmann, W. 310, 130
Friend, I. 310, 520
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Fritz, D. 310, 120
Frnka, R. L. 310, 210
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Fromm, D. T. 310, 440
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Fry, R. C., Jr 310, 320
Fryman, R. F. 320, 010
Fu, L. Y. 310, 410
Fullerton, D. 320, 210
Furfero, A. J. 300, 100
Furrer, A. 310, 540
Gaciala, J. S. 320, 540
Gala, M. 310, 430
Galbis, V. G. 310, 120
Galbraith, J. A. 310, 910
Galbraith, J. K. 310, 320
Gale, J. R. 320, 310
Galeotti, G. 320
Galeppo, J. 310, 430
Galper, H. 320, 930
Gambill, J. D. 320, 900
Gamba, C. M. 310, 020
Gander, E. J. 310, 320
Gandhi, V. P. 320, 440
Gandolfi, A. E. 310, 400
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Garber, P. M. 310, 210
Garcia, G. G. 310, 130
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Garka, J. A. 320, 430
Garner, A. 310, 430
Garon, J. 310, 430
Gart, A. 310, 210
Garvy, G. 300, 130
Gasser, W. J. 310, 430
Gatti, J. F. 310, 520
Gauci, B. 310, 030
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Gebauer, W. 310, 030
Gelson, R. J. 310, 220
Gemayel, F. J. 310, 430
Gemello, J. M. 320, 940
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Gensemer, B. L. 320, 930
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Gerardi, G. 320
Gerdes, W. D. 310, 030
Germania, J. J. 320, 130
Germany, J. D. 310, 430
Gerring, L. F. 310, 940
Gestrin, B. V. 310, 430
Geyer, H. G. 320, 020
Ghandhi, J. K. S. 310, 120
Ghazalah, I. A. 320, 810
Ghilarducci, M. T. 320, 830
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Gibson, W. E. 310, 430
Gieber, G. 310, 130
Giertz, J. F. 320, 020
Gifford, A., Jr 320, 020
Gigliotti, R. R. 320, 640
Gilbert, R. A. 310
Gilbert, R. D. 310, 430
Gilbreath, W. J. S. 310, 520
Gilles, C. 310, 210
Gillette, C. C. 310, 020
Gilmer, R. W. 320, 210
Girton, L. 300, 430
Glasner, D. 310, 020
Glassman, J. E. 300, 200
Glenday, G. 320, 820
Goddard, H. C. 320, 720
Goddeeris, J. H. 320, 910
Godshaw, G. 320, 400
Goetz, M. L. 320, 020
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Gold, R. E. 320, 610
Gold, S. 320, 720
Gold, S. D. 320, 930
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Goldstine, A. D. 300, 400
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Goode, R. B. 320, 120
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Goodman, R. J. B. 310, 210
Gootzeit, M. J. 310, 060
Gordon, R. H. 320, 520
Gordon, R. J. 300, 130
Gorski, M. C. 310, 320
Gouke, C. G. 310, 830
Grady, P. M. 320, 130
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Gramley, L. E. 310, 130
Gramm, W. P. 300, 040
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Graves, L. F. 310, 010
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Gray, J. A. 320, 720
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Gray, M. R. 300, 430
Green, J. K. 320, 540
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Greene, J. E. 320, 810
Greene, K. V. 320, 930
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Greenwood, J. 310, 430
Gregory, K. D. 300, 810
Gregory, O. K. 310, 520
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Grieson, R. E. 320, 930
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Griffith, P. S. 320, 510
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Groenewold, N. 320, 310
Gronouski, J. A. 320, 510
Gross, S. M. 300, 800
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Grosskopf, S. 320, 820
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Guerneey, G. T., IV 300, 500
Guitkin, B. 310, 520
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Gupta, K. L. 300, 100
Gurwitz, A. S. 320, 930
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Guthrie, A. L. 310, 130
Guttentag, J. M. 310, 930
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Hagan, D. G. 310, 130
Hahm, S. 310
Hahn, P. J. 310, 320
Heiner, J. J. 320, 910
Hall, C. W. 310, 010
Hall, T. E. 300, 210
Hall-Martindale, D. 320, 800
Halvorsen, R. 320, 720
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Hamberg, D. 310, 020
Hamilton, J. A. 310, 430
Hamilton, J. H. 320, 610
Hamilton, K. N. 310, 610
Hamm, W. G. 320
Hammond, J. D. 310, 430
Hamner, H. H. 310, 320
Hamovitch, W. 320, 940
Hampel, W. F. 310
Hanc, G. 310, 320
Handler, H. J. 310, 430
Haney, R. L., Jr 310, 720
Hansen, M. H. 310, 130
Hanson, E. J. 320, 610
Hanson, R. X. 310, 160
Hanusch, H. 320, 900
Hanweck, G. A. 310, 210
Harberger, A. C. 320, 110
Harford, J. D. 320, 610
Haritakis, N. 310, 610
Harju, M. W. 310, 520
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Harold, L. 310, 320
Harris, R. B. 320, 800
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Harrison, J. W. 320, 200
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Harshberger, R. B. 310, 020
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Hartle, D. G. 320
Hartman, D. G. 320, 440
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Hashemi, M. F. 310, 430
Hashimoto, T. 320
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Haus, L. W. 320, 720
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Hawawini, G. 310, 520
Hayashi, P. M. 310, 210
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Hehman, D. 310, 020
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Heinonen, A. 310, 000
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Helwig, M. F. 310, 020
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Henke, K. 320, 910
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Hicks, S. S. 300, 130
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Hirata, J. 310, 210
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Howson, S. K. 310, 430
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Hsieh, C. T. 310, 210
Hubbard, R. G. 310, 320
Huckins, L. E. 320, 930
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Humphrey, J. F. 310
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Hunter, W. J. 320, 930
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Ihori, T. 320, 430
Inagaki, H. 310, 430
Incer, R. 310, 320
Infinger, M. L. 320, 520
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Issing, O. 310, 430
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Jallow, R. 300, 130
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Jaramillo-Vallejo, J. 310, 130
Jarchow, H. 310, 430
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Jenkins, G. P. 320, 100
Jennings, G. W. 310, 030
Jensen, F. H. 310, 430
Jessee, M. A. 310, 610
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Jhun, U. 320, 020
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Jones, D. S. 300, 200

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Jones, L. D. 310, 520
Jones, O. H. 310, 320
Jones, S. L. 310, 320
Jones, W. R. 310, 520
Jones-Hendrickson, S. B. 320, 210
Jonung, L. 310, 130
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Jordan, W. J. 320, 610
Jorgenson, L. P. 300, 520
Joshua, J. 320, 500
Jost, G. 310
Jump, B. 320, 930
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Kang, M. H. 310, 400
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Kantor, L. G. 310, 520
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Karacaoglu, G. 310, 430
Karakitsos, E. 310, 130
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Kaufman, H. 300, 000
Kaufman, H. M. 310, 210
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Keith, E. G. 320, 310
Keleher, R. E. 310, 940
Kelty, P. L. 310, 520
Kempey, W. M. 310, 320
Kendall, D. L. 310, 520
Kent, R. J. 310, 130
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Redman, M. B. 310, 320
Reeder, R. J. 320, 210
Reeder, W. J. 320, 400
Reeve, J. E. 310, 320
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Reichert, A. K. 310, 020
Reid, W. J. 320, 610
Reidenbach, M. 320, 930
Reinertsen, T. R. 300
Reinhard, R. M. 320, 930
Reinhardt, H. 310, 520
Renfer, K. M. 320, 540
Renshaw, G. T. 300, 400
Reshen, B. 300, 520
Resler, D. H. 310, 320
Rethwisch, K. 320, 040
Reuss, F. G. 320, 310
Revier, C. F. 320, 020
Reyes-Heroles, J. F. 310, 110
Rhoda, K. L. 310, 520
Ribeiro, C. A. 300
Richards, G. R. 320, 310
Richardson, J. A. 300, 130
Richman, R. L. 320, 930
Ricker, C. S. 310, 520
Ridgway, T. R. 310, 210
Rieder, M. E. 310, 220
Riedy, M. J. 310, 320
Riew, J. H. 320, 020
Ritter, L. S. 310, 320
Rivard, R. J. 310, 520
Rivlin, A. M. 320, 820
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Roberts, J. C. 310, 430
Roberts, W. W. 310, 400
Robertson, L. S. 300, 400
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Robinson, T. R. 310, 130
Robinson, T. R. 320, 910
Robinson, W. J. 320, 210
Rocha, L. J. 310, 410
Roche, E. P. 320, 600
Rock, J. M. 310, 020
Rodgers, G. B. 300, 630
Rodrigues, R. I. 320, 520
Rodriguez, A. J. 310, 520
Roge, J. J. 300, 210
Rogozinski, J. 320, 940
Roley, V. V. 310, 210
Rolnick, A. J. 310, 210
Rolph, E. R. 300, 030
Romani, F. 320
Romer, T. 320, 020
Ronk, S. S. 310, 320
Rosado, A. L. 320, 520
Rose, A. K. 310, 430
Rose, H. B. 310, 130
Rose-Ackerman, S. 300, 930
Roseman, M. R. 300, 130
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Rosen, H. S. 320, 210
Rosen, H. S. 320, 810
Rosen, L. J. 320, 910
Rosenbaum, E. 310, 030
Rosenbaum, M. S. 310, 210
Roskamp, K. W. 320, 310
Ross, C. R. 310, 320
Ross, J. A. 310, A00
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Ross, M. 320, 830
Ross, M. H. 300
Ross, R. H. 320, 940
Ross, S. 310, 020
Rossiter, R. D. 310, 210
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Rotemberg, J. J. 310, 210
Rotheim, R. J. 310, 030
Roussakis, E. N. 310, 420
Roussesa, S. W. 310, 020
Rowe, J. L. 300, 400
Rowe, J. Z. 310, 040
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Roy, P. N. 320, 720
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Ruebling, C. E. 310, 320
Rugina, A. 300, 030
Ruhmann, P. 310, 430
Rukstad, M. G. 310, 210
Rupley, L. A. 320, 120
Russ, M. L. 320, 120
Russek, F. S. 320, 010
Rust, J. P. 310, 210
Ruth, H. L. 320, 810
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Ryan, T. P. 320, 020
Sabatacakis, P. K. 310, 210
Sabbarese, D. M. 310, 020
Sacerdoti, E. 310, 010
Sadka, E. 320, 930
Saffran, B. 320, 000
Sagan, J. 310
Sahasakul, C. 320, 310
Sahota, G. S. 320, 100
Salamanca, M. 310, 430
Salemi, M. K. 310, 210
Salley, C. D. 310, 030
Salvemini, G. 320, 220
Sametz, A. W. 310, 440
Sanders, H. 320, 220
Sands, M. R. 310, 020
Sanford, D. Z. 300, 830
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Savary, J. R. 310, 930
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Scanlon, M. S. 310, 210
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Schmidt, K. 320, 310
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Schwartz, A. J. 310, 130
Schwartz, E. 310, 520
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Schwartz, M. D. 320, 900
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Seidel, E. A. 310, 520
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Seja, J. 310, 610
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Shin, K. 310, 520
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Short, E. A. 310, 110
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Spilde, R. H. 310, 520
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Stein, S. H. 310, 020
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Stephanos, G. 310, 210
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Steve, S. 320, 910
Stevens, J. L. 310, 520

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Strauss, R. P. 320, 830
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Synnott, T. W. 300, 430
Szopo, P. 310, 430
Szturma, W. C. 300, 210
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Tanzer, E. P. 320, 210
Tanzi, V. 320, 130
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Tatsumi, K. 310, 320
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Taylor, N. L. 300, 130
Taylor, R. G., Jr 310, 210
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Teeters, N. H. 320, 310
Teichmann, U. 300, 800
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Thiel, E. 320, 940
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Tollen, R. D. 310, 520
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Topham, N. 320, 020
Torto, R. G. 320, 310
Tost Xifra, F. 320
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Townsend, S. B. 320, 720
Trask, G. M. 320, 310
Trask, J. H. 320, 610
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Tsiang, S. C. 300, 400
Tsiepas, S. A. 310, 400
Tsumba, L. L. 300, 400
Tuccillo, J. 310, 930
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Tuckman, H. P. 320, 850
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Tufte, E. R. 310, 220
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Turner, R. G. 300, 800
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Turner, T. L. 310
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Urich, T. J. 310, 520
Usip, E. E. 310, 210
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Van Dahm, T. E. 310, 020
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Van Hoose, D. D. 310, 610
Van Huyck, J. B. 300, 410
Van Poeck, A. 310, 400
Van Winden, F. 300, 600
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Varsano, R. 320, 420
Varvares, C. P. 310, 230
Vaughan, C. M. 320, 930
Vazquez, J. M. 310, 520
Veall, M. R. 320, 210
Vehorn, C. L. 320, 930
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Vellrath, M. 310, 320
Venton, J. P. 300, 320
Verbit, G. P. 320, 930
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Verdon-D'Amours, B. Y. 310, 110
Vernon, J. R. 310, 020
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Villarreal, A. 300
Vincent, P. E. 320, 930
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Vinson, J. R. 310, 010
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Vogel, R. C. 300, 100
Vogel, R. J. 320, 910
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Von Der Ohe, R. 310, 130
Von Furstenberg, G. M. 320, 310
Von Wangenheim, E. 300, 400
Von Zur Muehlen, P. 310, 020
Vorst, K. S. 310, 210
Vrooman, D. H. 310, 010
Vuchelen, J. F. 310, 210
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Wagstaff, J. V. 320, 030
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Waldo, A. D. 320, 940
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Wall, E. L. 310, 000
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Wallace, N. 310, 430
Wallace, R. H. 310, 810
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Walsh, C. E. 310, 130
Walsh, W. 310, 320
Walters, J. M. G. 310, 430
Walton, J. K., II 310, 210
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Warren, S. A. 310, 320
Wasmuth, V. 320, 020
Wassom, J. C. 310, 020
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Watson, J. O. 300, 210
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Webb, S. C. 310, 130
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Weber, W. E. 300, 210
Webster, P. M. 310, 130
Weck, H. M. 300, 200
Wegner, R. C. 320, 810
Weicher, A. L. 310, 210
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Weinschrott, D. J. 320, 210
Weisbrod, B. A. 320, 910
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Weisser, M. 320, 110
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Welki, A. M. 320, 930
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Wessels, R. E. 310
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Westphal, U. 310, 130
Weyforth, W. O. 310, 130
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Wicker, W. E. 300, 000
Wicks, J. H. 320, 000
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Willits, R. W. 320, 210
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Willms, M. 310, 430
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Yunker, J. H. 300, 600
Yurtchuk, J. R. 310, 520
Zabrenski, S. T. 310, 220
Zarnowski, C. F. 300, 010
Zayas, E. R. 310, 610
Zee, H. H. 320, 310
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Zelder, R. E. 310, 930
Ziemes, G. P. 320, 820
Zimmerman, C. F. 320, 720
Zimmerman, D. 320, 930
Zimmerman, R. O. 310, 020
Zimmermann, H. 320, 940
Zins, P. J. 310, 610
Zoda, J. C. 310, 110
Zodrow, G. R. 320, 930
Zorn, C. K. 320, 930
Zorn, E. C. 310, 010
Zuberi, H. A. 300, 120
Zubrow, R. A. 320, 930

400 INTERNATIONAL ECONOMICS

410 INTERNATIONAL TRADE THEORY
420 TRADE RELATIONS, COMMERCIAL POLICY, ECONOMIC INTERGRATION
430 BALANCE OF PAYMENTS, INTERNATIONAL FINANCE
440 INTERNATIONAL INVESTMENT AND FOREIGN AID

Abbott, J. M. 400, 300
Abdulshad, F. 410, 300
Abrahamsson, B. J. 400, 620
Abrams, R. K. 430, 310
Abuaf, N. 430, 520
Adam, C. M. 430, 210
Adamovich, L. S. 420, 410
Adler, R. W. 430, 320
Agarwal, J. P. 440, 430
Aghevli, B. B. 400, 200
Agnew, R. A. 410, 830
Aharoni, Y. 440, 510
Ahmad, J. 400, 120
Ahn, H. 430, 210
Ahn, S. C. 430, 310
Aho, C. M. 400, 210
Ahtiala, K. P. 430, 310
Aiello, P. M. 400, 300
Aitken, N. D. 400, 300
Akano, S. O. 410, 440
Akiba, H. 410, 210
Alano, B. 420, 840
Alexander, W. D. 440, 520
Aliber, R. Z. 430, 440
Al-Kulaib, S. M. 440
Allen, P. R. 430, 420
Allen, S. D. 430, 310
Allgeier, P. F. 400, 120
Alonso, J. F. 410, 020
Alter, G. M. 440, 110
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Alvis, V. Q. 430, 310
Amaral, R. C. 400, 430
Ambach, D. R. 400, 300
Anderson, J. E. 410, 420
Anderson, K. 400, 710
Anderson, L. E. 410
Anderson, R. K. 410, 430
Andrews, R. B. 400, 120
Andrews, J. E. 420, 430
Andrews, M. D. 400, 610
Aoki, M. 430, 310
Apostolides, A. D. 400, 600
Appleyard, D. R. 400, 110
Aquino, A. 400, 620
Areskoug, K. 440, 430
Arispe-Caceres, E. 430, 210
Armas, A. C., Jr 400, 600
Armington, P. S. 430, 410
Arndt, S. W. 400, 310
Arrill, D. 440, 430
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Askari, H. 400, 110
Aspe, P. 430, 130
Atkins, C. A. 430, 520
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Baksh, M. K. 400, 000
Balassa, B. A. 420, 120
Baldwin, R. E. 400, 110
Bale, H. E. 410, 430
Bale, M. D. 420, 710
Balicka, S. M. 440, 900
Balough, R. S. 440, 210
Baran, E. M. 440, 300
Barbosa, A. M. 430, 300
Bardach, K. C. 430, 310
Bardon, J. E. 420, 440
Barlow, W. D. 440, 630
Barrett, A. 430, 410
Barsony, A. 400, 120
Bartel, R. D. 400, 300
Bartel, R. J. 430, 040
Basevi, G. 430, 410
Bassam, A. A. 400, 320
Batalier-Martin, F. 420, 120
Batemarco, R. J. 400, 310
Batra, R. N. 410, 120
Batten, D. S. 430, 210
Bauer, R. A. 400, 400
Baxter, T. M. 400, 210
Bayard, T. O. 420, 430
Beals, R. E. 420, 210
Becker, S. J. 400, 100
Beckett, G. 420, 040
Beenhakker, A. 400, 520
Behnke, E. 430, 310
Behrens, H. W. 400, 310
Beigie, C. E. 400, 610
Bell, A. T. 430, 410
Belli, P. A. 420, 120
Bender, D. 400, 120
Bensky, J. M. 440, 420
Benvignati, A. M. 440, 620
Berengaut, J. 430, 420
Bergsten, C. F. 430, 440
Bergstrand, J. H. 430, 410
Berner, R. B. 400, 210
Bernstein, E. M. 430, 310
Bertin, G. Y. 440, 620
Beshoar, J. M. 420, 040
Bigman, D. 430, 020
Bilson, J. F. O. 430, 310
Blakup, R. 420, 050
Blackhurst, R. 400, 600
Blackman, H. N. 400, 800
Blair, A. R. 420, 440
Blalock, J. E. 430, 310
Blanchette, H. A. 420, 430
Blandford, D. 420, 710
Blaxall, M. O. 420, 610
Blejer, M. I. 430, 310
Bloch, H. S. 430, 440
Bloomfield, A. I. 430, 310
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Blumenthal, W. M. 400, 500
Boarman, P. M. 400, 000
Bobe, B. 420, 320
Boehm, T. P. 430, 940
Boehnke, R. W. 420, 610
Bogart, F. A. 440, 520
Boltuck, R. D. 410, 430
Bomberger, C. L. 430, 020
Bond, E. W. 410
Bond, I. D. 410, 300
Bond, M. E. 430, 010
Bond, M. E. 430, 410
Borchert, M. 400, 310
Borkin, J. 440, 000
Borta, G. H. 400, 900
Botsas, E. N. 420, 050
Bottcher, B. 400, 610
Bourget, J. A. H. 410, 610
Bourgoin, E. 400, 120
Bourguinat, H. L. 400
Bove, F. 400, 120
Bowen, H. P. 410, 210
Boyd, D. L. 400, 710
Boyer, G. K. 410, 820
Boyer, R. S. 430, 310
Bragdon, M. C. 420, 110
Brander, J. A. 410, 610
Brandis, R. B. 420, 440
Branson, W. H. 430, 410
Bray, W. H. 430, 610
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Brecher, I. 420, 440
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Bristol, L. J. 430, 020
Brittain, W. H. B. 430, 310
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Brown, J. P. 400, 720
Brown, K. H. 430, 440
Brown, S. B. 400, 100
Brown, W. B. 400, 530
Brown, W. M. 430, 130
Bruck, N. 430, 110
Brust, P. J. 430, 310
Bryan, I. A. 420, 630
Bryan, W. 420, 110
Bryant, R. C. 400, 310
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Cabarrouy, E. A. 400, 120
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Campbell, J. Y. 430, 310
Canela, L. A. 420, 110
Capalbo, S. M. 420, 720
Caprio, G., Jr 430, 420
Carbaugh, R. J. 430, 610
Cardemil, L. A. 430, 210
Carey, R. H. 400, 100
Carlisle, E. R. 420, 430
Carlozzi, N. 430, 310
Carpenter, K. C. 430, 310
Carratt, C. A. 430, 440
Carter, C. A. 410, 710
Casas, F. R. 410, 430
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Cassing, J. H. 410, 020
Castol, R. G. 420, 320
Cavanaugh, K. L. 430, 210
Cernohous, Z. 430, 440
Cervantes-G, J. 430, 410
Cervin, R. 410, 430
Chacholiades, M. 410, 430
Chaffee, D. M. 420, 120
Chalfant, J. A. 400, 710
Chan, K. 430, 720
Chang, A. W. 430, 020
Chang, W. W. 410, 020
Chao, J. T. C. 420, 310
Chapleau, P. 410, 210
Chapman, B. R. 420, 300
Chaumont, P. 420, 000
Chen, J. 430, 130
Chen, N. T. 420, 010
Chesen, J. R. 420
Chiang, T. C. N. 430, 210
Chibba, M. M. 400, 100
Chin, R. Q. P. 400, 120
Chipman, J. S. 400, 210
Chirurg, J. T. 430, 440
Chittle, C. R. 420, 050
Choi, J. J. 400, 110
Choo, M. 420, 320
Choudhri, E. U. 400, 130
Chowdhury, M. M. A. 400, 200
Chrimes, N. R. 400, 700
Chrystal, K. A. 430, 310
Chu, B. Y. 400, 210
Chuang, L. 400, 100
Chudson, W. A. 400, 110
Chugh, R. L. 400, 110
Chung, J. W. 410, 210
Claassen, E. 430, 300
Clague, C. K. 400, 120
Claiborn, E. L. 430, 410
Clark, D. P. 410, 110
Clark, P. B. 430, 310
Clark, W. 430, 440
Claude, C. 440, 120
Claudon, M. P. 420, 610
Clawson, P. L. 400, 100
Clement, M. O. 400, 130
Clifton, E. V. 430, 110
Clyde, W. C. 410, 430
Cochran, H. A. 420, 410
Coelho, A. M. 400
Cohen, B. J. 430, 420
Cohen, M. B. 400, 600
Coletis, F. J. 400, 300
Coles, F. A., Jr 410, 110
Collado, E. G. 440, 320
Cominos, D. A. Z. 440, 110
Condon, T. J. 430, 610
Conn, H. D. 410, 010
Connolly, M. B. 410, 900
Connors, T. A. 430, 110
Contreras, M. G. 400, 500
Cook, M. T. 410, 310
Cooper, R. N. 430, 420
Coplan, L. M. 400, 210
Coppock, J. D. 400, 000
Corden, W. M. 400
Cordes, J. A. 400, 720
Cordoba, D. T. 420
Cornell, B. 430, 310
Cornell, R. A. 410, 420
Cornford, A. J. 430, 600
Cory, P. F. 400, 050
Coughlin, C. C. 440, 420
Cowen, R. K. 420, 130
Craig, G. A. 430
Cross, L. R. 400, 500
Crouhy, M. G. 400, 500
Cucek, E. M. 430, 440
Cuddington, J. T. 400, 300
Cumper, G. E. 440, 910
Cunha, A. M. 400, 430
Curran, R. F., Jr 430, 040
Curzon, G. 420, 430
Curzon-Price, V. 420, 440
Cushman, D. O. 430, 030
Dabbagh, M. A. 410, 940
Dahl, G. C. 420, 430
Dalal, A. J. 400, 020
Dale, C. J. 430, 310
Dalton, A. H. 430, 830
Daly, D. J. 420, 110
Daniel, A. D. 410, 320
Daniel, B. C. 430, 310
Danielsen, A. L. 400, 720
Dare, B. R. 440, 120
Das, S. P. 410, 020
Davison, C. S. 400, 100
Deardorff, A. V. 410, 430
Deboer, E. J. 420, 440
Deflori, B. A. 420, 210
de Fontenay, P. B. 430, 300
Degen, R. A. 430, 310
Degrauwe, P. 430
Dehem, R. 400, 030
Delbruck, P. G. 420, 520
Dellalfar, W. A. 430, 310
De Macedo, J. A. B. 430, 020
Demonteix, Y. 430, 310
Denis, J. 420, 440
Dernburg, T. F. 430, 300
Deroea, D. A. 420, 430
Devlin, D. T. 430, 130
Devries, B. A. 400, 600
Devries, M. G. 430, 420
Diaz-Alejandro, C. F. 420, 120
Dickie, P. M. 430, 520
Dieboid, W. 400, 610
Dietrich, J. K. 430, 310
Dixit, A. K. 410, 610
Djajic, S. 400
Djiwandono, J. S. 430, 310
Doenges, B. F. 420, 220
Dohner, R. S. 410, 430
Dompierre, M. B. 410, 420
Donahue, J. C. 430, 130
Donnelley, L. P. 400, 720
Donnelly, W. F. 420, 040
Donner, O. 400, 130
Dooley, M. P. 430, 310
Dornbusch, R. 400, 310
Douglass, G. K. 420, 120
Doyle, G. A. 400, 100
Dragon, G. 440, 510
Drewry, L. A. 430, 510
Dreyer, J. S. 430, 440
Driskill, R. A. 430
Droucopoulos, V. 440, 210
Dubrow, M. L. 420, 020
Duda, P. A. 430, 310
Dudley, L. M. 400, 120
Duell, D. C. 430, 210
Duncombe, B. F. 400, 320
Dunlevy, J. A. 430, 800
Dunn, R. M., Jr 430, 440
Durand, E. E. 430, 440
Durkin, J. T. 400, 720
Dutton, J. C. 400, 800
Eaker, M. R. 430, 520
Eastman, H. C. 430, 420
Eaton, J. 400, 300
Eberle, P. P. 430, 130
Economides, C. 430, 130
Eddy, E. D., III 420, 110
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Edison, H. J. 430, 210
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Edwards, T. L. 400, 120
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Ekers, E. N. 400, 530
Eichlbegoff, I. M. 420, 720
El-Kuweiz, A. I. 400, 120
Elliott, V. L. 440, 110
Ely, M. E. C. 400, 120
Emery, R. F. 430, 310
Enders, W. 430, 310
Eng, M. V. F. 400, 520
Engelsen, E. G. 430, 420
Enoch, C. A. 420, 430
Erdilek, A. 420, 440
Escobar, L. E. 400, 720
Escoube, W. E. 430, 440
Estebanez, G. 430, 210
Ethier, W. J. 400, 020
Evans, E. L. 440, 430
Ezzati, A. 400, 720
Fager, G. B. 430, 120
Fakhrais, B. 410, 110
Falvey, R. E. 420, 410
Farah, M. G. 400, 100
Farbman, M. 440, 820
Farsed, A. M. E. 400, 920
Farrag, N. M. 440, 720
Faulhaber, B. C. 400, 500
Fausten, D. K. 430, 030
Fekatekuty, G. 400, 000
Feldman, D. H. 410, 430
Feldman, G. M. 440
Feldman, R. A. 400
Feldsieper, M. 400, 320
Fels, G. 420, 600
Feisenthal, L. 420, 110
Fenton, H. M. 440, 120
Ferreira, O. S. 420, 510
Feuerlein, W. J. 430, 420
Feulner, E. J., Jr 420, 510
Ffrench-Davis, R. 400, 100
Fiekowsky, H. F. 420, 830
Field, P. B. 420, 430
Finger, J. M. 410, 420
Finkel, E. J. 440, 430
Fisher, D. A. 430, 010
Fitchett, D. A. 440, 720
Fitzsimmons, W. A. 430, 310
Flassbeck, H. 430, 310
Fleisig, H. 400, 040
Flynn, E. H. 430, 320
Formoso, J. P. 430, 440
Foroutan, F. 420, 630
Forster, L. A. 430, 310
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Franco, R. 430, 440
Frank, I. 420, 110
Frankel, J. A. 430, 310
Franklin, P. E. 420, 610
Franko, L. G. 400, 600
Frederick, J. R. 430, 800
Freeman, R. T. 440, 430
Frenkel, J. A. 400, 310
Fried, H. O. 410, 020
Friedman, I. S. 400, 100
Friesen, R. L. 400, 100
Fujioka, M. 430, 440
Fuller, S. 410, 720
Furth, J. H. 430, 030
Furtney, G. W. 410, 010
Gaines, D. B. 410, 020
Gamby, R. R. 420, 120
Gandhi, P. P. 420, 110
Gandolfo, G. 400, 210
Ganiatsos, T. G. 440, 620
Garcia, A. 420, 110
Garcia-Garcia, J. 400, 300
Gardner, G. W. 430, 310
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Garretson, D. P. 400, 100
Gaspar, J. E. 430, 310
Geiger, L. T. 440, 110
Geiger, T. 400, 100
Geisert, W. F. 400, 010
Gemmill, R. F. 430, 310
George, W. M. 400, 100
Georgiou, G. C. 420, 120
Gernant, P. L. 420, 310
Gerra, M. J. 430, 210
Ghasemzadeh, D. 410, 210
Ghilardi, J. F. L. 430, 440
Ghosh, D. K. 410, 020
Ghoshal, A. 400, 020
Giannitsis, A. 440, 610
Giblin, J. D. 400, 810
Giddy, I. H. 430, 310
Gillespie, R. W. 430, 440
Gillin, E. D. 400, 800
Gillmore, C. W. 400, 130

Gilman, M. G. 430, 440
Ginman, P. J. 420, 120
Gionfriddo, S. J. 420, 440
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Glantz, H. H. 400, 000
Glassman, D. A. 430, 210
Glendening, R. N. 410, 320
Glick, R. 400, 310
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Goerres, A. 430, 820
Goertz, H. A. 400, 020
Goisis, G. 410, 910
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Golden, J. R. 400, 210
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Goldstein, H. N. 430, 420
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Gonye, L. K. 420, 040
Goodman, H. H. 420, 630
Goodman, I. B. 430, 410
Goodman, S. H. 430, 520
Goodman, S. S. 430, 420
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Gordon, W. C. 400, 020
Graf, G. 430, 410
Graham, E. M. 420, 620
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Grant, J. H. 430, 210
Grassman, S. 430, 420
Gray, H. P. 410, 430
Gray, J. A. 430, 310
Grayson, L. E. 440, 720
Grebe, H. 410, 030
Green, A. W. 420, 430
Green, T. M. 420
Greenberg, L. J. 430
Greene, M. L. 400, 300
Grennes, T. J. 430, 410
Grindea, D. 400, 030
Grinols, E. L., III 410, 020
Grosse, R. E. 440, 420
Grossman, G. M. 410, 110
Grove, D. L. 400, 100
Grubel, H. G. 400, 000
Guinot, J. L. 400, 010
Guisinger, S. E. 420, 120
Guissarri, A. C. 430, 310
Gupta, S. 420, 430
Gursel, H. F. 430, 300
Gutierrez, A. D. 420, 110
Gutowski, A. F. 400, 300
Habberton, E. F. 420, 810
Haberler, G. 410, 130
Hackett, J. W. 400, 300
Hadjiyanis, D. P. 400, 050
Hager, P. G., III 400, 120
Hakkio, C. S. 430, 210
Hallberg, K. M. 400, 210
Hallow, M. J. 430, 310
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Hammer, O. H. 440, 520
Hammond, C. 430
Handerson, H. B. 400, 610
Hanel, P. 400, 620
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Hansen, J. R. 430, 320
Hanson, J. S. 420, 440
Happe, N. L. 400, 120
Harden, W. R. 400, 310
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Harmon, B. M. 410, 430
Harrington, J. M., Jr 400, 210
Harrington, R. W. 410, 020
Harris, R. L. P. 440, 710
Hartland-Thunberg, P. 400, 100
Hasenberg, W. 400, 320
Hasson, J. A. 400, 020
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Hawkins, R. G. 430, 420
Hawley, F. W. 400, 300
Haynes, S. E. 430, 210
Healy, J. P. 400, 310
Heatherington, D. F. 430, 440
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Helman, V. M. 420, 110
Helpman, E. 400, 320
Hemphill, W. L. 400, 130
Henderson, D. W. 430, 310
Hennart, J. 440, 050
Henry, G. B. 400, 310
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Heri, E. W. 430, 310
Herring, R. J. 430, 300
Hersey, A. B. 430, 310
Hervey, J. L. 420, 710
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Hettena, R. 410, 000
Heung, S. F. 430, 520
Heuson, W. G. 430, 520
Heymann, H., Jr 400, 620
Hicks, R. P. 400, 310
Hillman, A. L. 400, 320
Hillmann, J. F. 400, 600
Hilty, D. P. 400, 130
Himarios, D. D. 430, 310
Hinestrosa, F. 400, 110
Hinkle, L. E. 400, 100
Hinshaw, R. 430, 420
Hippie, F. S. 400, 600
Hirsch, S. 420, 440
Hirschtritt, R. 430, 440
Ho, D. S. 400, 200
Hoag, M. W. 430, 020
Hochreiter, E. H. 430, 310
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Hodgson, J. S. 430, 410
Hodrick, R. J. 430, 310
Hoekendorf, W. C. 400, 050
Hofmann, D. M. 430, 310
Holbik, K. 430, 310
Holden, P. 410, 430
Hollerman, L. 400, 120
Holmes, P. M. 420, 110
Holroyd, W. M. 420, 410
Holzman, F. D. 420, 050
Homan, A. G. 430, 520
Hong, W. 400, 120
Hood, W. C. 430, 300
Hoopengardner, T. A. 440, 430
Hooper, P. 430, 210
Hornig, E. C. 420, 820
Horst, T. O. 440, 610
Horvath, J. 440, 020
Howell, A. H. 440, 120
Hoyer, W. H. 410, 620
Hoyt, E. E. 400, 900
Hsiao, L. L. 410, 430
Hsieh, D. A. 430, 210
Hu, O. S. Y. 400
Huber, J. H. 430, 440
Hudgins, M. W. 430, 310
Huefner, M. 430, 310
Hufbauer, G. C. 410, 440
Hughes, K. H. 420, 440
Hugonnier, B. C. 440, 430
Hultman, C. W. 430, 440
Hummel, L. 400, 100
Hummel-Kowalski, M. 440, 320
Hung, T. Q. 400
Hunsberger, G. E. 420, 030
Hunsberger, W. S. 420, 120
Husband, D. 400, 210
Husted, S. L. 410, 430
Hutcheson, H. H. 400, 000
Hutchinson, E. B. 430, 900
Hyson, C. D. 440, 720
Ibarra, A. 430, 600
Iffland, C. 440, 120
Ike, B. 420, 620
Ingram, J. C. 400, 110
Iodice, E. 400
Isard, P. 430, 300
Isaza-Botero, R. 430, 840
Ishimine, T. 420, 440
Issa, F. S. 410, 130
Itagaki, T. 400, 200
Iwanaka, G. M. 400, 300
Iyoha, M. A. 430, 210
Jackendoff, N. 430, 310
Jackson, S. 400, 010
Jacobs, G. R. 420, 440
Jacobson, L. R. 400, 720
Jacobson, M. H. 400
Jacquillat, B. H. 430
Jadlow, J. W. 400, 600
James, A. 400, 630
Jay, K. E. 400, 110
Jelacic, J. E. 400, 720
Jenab, P. 410, 110
Jennings, T. F. 420, 110
Jesmok, D. M. 430, 310
Jespersen, J. 430, 310
Jessewein, W. A. 410, 940
Jewett, C. A. 420, 110
Jimenez-Ortiz, R. 400, 000
Johnson, P. R. 410, 210
Johnson, R. 430, 310
Johnson, R. A. 400, 100
Jones, R. W. 410, 020
Jones, W. E. 400, 210
Joy, J. 400, 100
Joyce, J. P. 430, 310
Juatas, H. R. 420
Juhl, P. G. 440, 110
Jul, A. M. 430, 320
Junz, H. B. 400, 300
Kadragic, A. M. 440, 520
Kaempfer, W. H. 410, 420
Kagan, S. 430, 440
Kahl, G. H. 440, 720
Kaiser, R. A. 420, 310
Kaji, M. 400, 110
Kalia, M. S. 410, 110
Kamm, J. O. 400, 300
Kan, K. 400
Kan, L. 440, 720
Kandaswamy, S. 430, 200
Kang, C. W. 420, 120
Kang, S. S. 430, 210
Kant, C. 400, 210
Kaplan, J. J. 430, 440
Kaplan, P. 400, 800
Kapp, W. R. 430, 440
Karim, S. H. A. 400
Karlik, J. R. 430, 420
Kasper, W. E. 400, 100
Katayama, S. 430, 310
Katseli-Papaefstratiou, L. T. 400, 100
Katz, B. S. 400, 100
Katz, E. 430, 020
Katz, J. L. 420, 710
Kaufman, R. H. 400, 100
Kaufmann, H. M. 420, 430
Kaufmann, J. 400
Kaufold, H. S. 430, 520
Kawai, M. 430
Kawamura, I. 440, 110
Kawar, S. 430, 310
Keilman, M. H. 400, 100
Kelly, F. J. 430, 520
Kelly, M. G. 430, 320
Kelly, W. B., Jr 420, 430
Kenen, P. B. 430, 410
Kenkel, J. J. 420, 440
Kennedy, I. C. 410, 610
Kennedy, M. E. 430, 310
Kiguel, M. A. 430, 310
Kim, C. 430, 210
Kim, I. 410, 720
Kim, J. C. 430, 310
Kim, K. 430, 520
Kim, K. S. 400, 110
Kimberland, K. G. 440, 120
Kimbrough, K. P. 400, 320
Kimura, Y. 440, 610
King, H. W. 430, 310
Kipokola, J. P. 420, 320
Kirkpatrick, C. M. 420, 210
Kiser, J. H. 420
Kitamura, H. 410, 420
Klein, G. W. 430, 310
Klein, R. M. 420, 440
Klein, T. M. 440, 430
Klimesz, H. R. 420, 530
Klopstock, F. H. 430, 440
Knezevich, H. 430, 050
Knopf, H. A. 420, 050
Kochanek, A. 400, 010
Kock, R. 420, 610
Kohlhagen, S. W. 430, 310
Kohli, U. R. 400, 210
Kohsaka, A. 430, 310
Komus, D. 440, 610
Koo, A. Y. C. 410, 020
Koo, B. 440, 630
Koo, S. 400, 220
Kopita, G. F. 440, 210
Korp, R. V. 430, 440
Kortan, J. J. 410, 940
Kost, W. E. 400, 710
Kostecki, M. 420, 110
Kouri, P. J. K. 400, 130
Kovacs, P. E. 400, 520
Kozub, J. J. 440, 700
Kramer, A. M. 430, 310
Krause, L. B. 430, 420
Kravis, I. B. 420, 220
Kreider, C. D. 420, 310
Kreinin, M. E. 400, 020
Kreshover, D. 400, 720
Kresl, P. K. 400, 040
Kressler, P. R. 400
Krieger, R. A. 430, 130
Kriz, M. A. 430
Krogh-Poulsen, N. E. 440, 610
Krol, R. 400, 020
Kroner, A. F. 430, 520
Krueger, A. O. 400, 100
Kruse-Kempen, E. 400, 300
Kryzda, B. F. 400, 300
Kudrle, R. T. 440, 610
Kuhn, W. E. 430, 420
Kumcu, M. E. 400
Kuo, C. 420, 820
Kupers, F. 400, 100
Kwack, S. Y. 430, 210
Kwok, V. P. 400, 520
Kwon, O. Y. 430, 130
Lage, G. M. 400, 020
Laird, S. 420
Lakhoua, F. 420, 800
Lallier, A. G. 400, 000
Landau, L. 440, 110
Landes, J. E. 400, 120
Lane, J. I. 410, 210
Laney, L. O. 430, 310
Lang, B. R. 430, 210
Langelan, M. J. 420, 610
Lanier, M. 420, 050
Lanjouw, G. J. 400, 310
Lanyi, A. M. 430
Lara-Resende, M. d. M. 400, 600
Larson, D. W. 410, 420
Lary, H. B. 400, 120
Lau, M. L. 430, 400
Law, A. D. 420, 320
Lawrence, R. Z. 420, 430
Layher, W. N. 400, 600
Layman, T. A. 400, 110
Leach, S. 430, 610
Leary, J. C. 420, 440
Lechner, H. H. 400, 930
Lederer, E. P. 430
Lederer, W. 430, 000
Lee, C. H. 440, 010
Lee, D. S. 410, 210
Lee, K. B. 400
Lee, K. T. 430, 310
Lee, W. 410, 020
Leftwich, R. B. 430, 410
Lehman, J. A. 400, 300
Leiber, D. J. 400, 200
Leiber, F. J. 400, 200
Leimone, J. E. 400, 110
Leipziger, D. M. 400, 100
Leister, D. V. 400, 520
Leith, J. C. 400, 100
Leonard, J. F. 430, 210
Lerdau, E. 400, 100
Lessard, D. R. 440, 520
Letiche, J. M. 400, 110
Leung, C. 430, 410
Levich, R. M. 430, 520
Levin, J. H. 430, 310
Lewins, L. 420, 050
Lewis, D. E. 410, 910
Lewis, M. D. 430, 110
Lewis, W. E. 400, 010
Li, J. 420, 210
Lightman, J. M. 420, 600
Lim, L. S. 430, 520
Lin, V. L. Y. 400, 600
Lin, Y. 410, 610
Lincoln, E. J. 420, 630
Lindsey, J. C. 400
Lipsey, R. E. 400, 220
Lipton, D. A. 400
Little, J. S. 430, 440
Liu, C. Y. 420, 710
Livingston, J. 430, 010
Lloyd, P. J. 410, 020
Lobo, O. H. 400
Logue, R. 430, 440
London, A. L. 430, 310
Lonergan, J. A. 430, 210
Lord, M. J. 420, 210
Los, C. D. 420, 620
Losman, D. L. 400, 600
Loud, F. V. 410, 430
Loughlin, J. C. 400
Loutfi, M. A. 410, 120
Lowinger, T. C. 400, 120
Lowrey, B. R. 430, 010
Lubbert, J. I. 400, 910
Lubich, B. H. 420, 320
Lubitz, R. 400, 110
Luis, L. R. 400, 210
Lurensky, R. L. 430, 440
Lynch, E. S. 430, 310
MacDonald, A. S. 400, 620
MacDonald, H. I. 420, 100
MacEwan, A. 420, 120
Machlup, F. 400, 600
MacRae, C. D. 400, 320
Maddox, G. B. 410
Maffucci, E. A. 420, 720
Magee, S. P. 410, 520
Maglera, S. L. 420, 130
Mahdi, S. I. 410, 110
Maitra, S. 430, 020
Major, H. 420, 620
Makin, J. H. 430, 310
Makkas, H. A. 430, 210
Maldonado-Bear, R. M. 440, 520
Malmgren, H. B. 400, 600
Malone, M. S. 420, 440
Manfredi, E. M. 400, 710
Marcus, E. 430, 310
Marer, P. 420, 430
Marin, D. 400, 310
Marion, N. P. 430, 020
Mark, C. T. 420, 430
Maroni, Y. 430, 120
Marston, R. C. 430, 310
Marthinsen, J. E. 430, 620
Martin, E. E. 410, 420
Martin, J. P. 410, 430
Martinez, A. E. 420, 430
Martinez, H. S. 440, 520
Martinez, R. C. 440, 430
Martirena-Mantel, A. M. 430, 130
Martone, C. L. 400, 310
Maskus, K. E. 400, 120
Mason, R. H. 440, 620
Massoudnia, M. E. 400, 200
Mathew, T. 410, 110
Mathieson, D. J. 430, 310
Mattsi, F. 410, 610
Matthews, J. R. 400, 310
Matthias, H. 420, 440
Maxwell, C. E. 430, 520
May, E. S. 420, 110
Mayer, L. A. 400, 800
Mayer, W. 410, 020
Mayhew, A. 400, 800
McCandless, G. T., Jr 430, 210
McCarthy, R. W. 410, 110
McClain, D. S. 430, 130
McColl, G. D. 400, 720
McCormick, F. E. 430, 310
McCrickard, D. L. 430, 410
McCulloch, R. 400, 620
McDermott, J. H. 430, 720
McGrath, E. L. 430, 520
McGuire, C. W. 420, 430
McGuirk, A. K. 430, 210
McHale, T. R. 400, 520
McKenzie, G. W. 410, 430
McKenzie, I. M. 430, 310
McKinney, J. A. 420, 120
McKinney, M. M. 420, 020
McKinnon, R. I. 400, 300
McLaughlin, G. E. 430, 120
McLeod, D. 400, 430
McMillan, C. H. 420, 050
McNeil, D. E. 420, 430
Meier, G. M. 400, 120
Meidau-Womack, E. C. 430, 320
Melvin, J. R. 410, 020
Menashe, I. 430, 310
Mendelowitz, A. I. 400, 600
Menkiatis, A. N. 400, 600
Merklein, H. A. 430, 720
Merrill, J. A. 400, 300
Merwin, C. L. 430, 440
Metcalf, J. E. 400, 100
Meyer, R. H. 430, 000
Meyer, S. A. 430, 310
Michaely, M. 400, 120
Michal, J. M. 430, 110
Mikesell, R. F. 400, 430
Miles, M. A. 430, 320
Miller, C. L. 440
Miller, L. C. 400, 500
Miller, W. D. 400, 200
Mills, J. L. 400, 520
Mintz, N. N. 420, 400
Mintzes, J. 400, 620
Mirus, R. 430, 310
Mirza, D. B. 430, 310
Misisco, H. P. 400, 210
Mitsos, A. G. J. 420, 430
Moeinian, B. 420, 010
Mohtadi, S. 420, 120
Mok, V. 400
Moller, H. 400, 310
Moller, J. O. 430, 620
Moisberger, J. 400, 610
Moisberger, M. 420, 800
Moncarz-Percal, R. 420, 810
Monke, E. A. 400, 100
Monroe, W. F. 430, 420
Monson, T. D. 420, 720
Montrie, C. J. 440, 110
Moore, C. T. 400, 320
Moore, D. A. 410, 420
Morales, G. 420, 310
Moran, T. H. E. 430, 600
Morgner, A. 400, 120
Morris, W. J. 400, 000
Moss, J. 420, 120
Moulton, J. M. 430, 310
Muller, P. 400, 610
Muller, R. 400, 100
Mundkowski, M. M. 440
Munoz, R. 420, 440
Muns, J. 400, 630
Murad, A. A. 400, 100
Murden, W. C. 430, 830
Murenbeeld, M. 430, 520
Murphy, D. R. 430, 310
Murphy, J. C. 400, 020
Murphy, R. G. 430, 310
Murray, J. D. 430, 310
Murray, T. W. 400, 120
Mutoh, T. 430, 020
Mutti, J. H. 420, 410
Myers, V. 400
Naim, M. 440, 610
Nanto, D. K. 420, 430
Nappi, C. 420, 720
Neary, J. P. 400, 320
Negrao, M. D. O. 440, 430
Nehmer, S. 420, 630
Nelson, G. J. 440, 430
Nelson, K. 400, 210
Netter, K. 420, 440
Neu, C. R. 430, 410
Neu, W. 410, 610
Neuhaus, P. 430, 120
Neumuller, R. 410, 210

Nicholas, C. J. 420, 530
Nickerson, G. W. 420, 430
Nimarko, A. G. 420, 110
Nixon, J. H. 440, 930
Nordyke, J. W. 400, 050
Normile, M. A. 400, 710
Norwood, B. 430, 420
Nothmann, R. S. 420, 430
Nye, W. W. 420, 430
Nyhus, D. E. 420, 210
Oakes, E. E. 440, 320
O'Brien, J. W. 400
Obatfeld, M. 430
Ocleirescain, S. 420, 210
O'Connell, S. A. 400, 210
Odawara, K. 400, A00
Officer, L. H. 420, 430
Ohly, J. H. 410, 430
Okonkwo, U. 400, 800
Okubo, S. 410, 110
Oliver, R. W. 430, 440
Ollila, J. J. 410, 430
Olsen, A. R. 400, 010
Olson, E. C. 430, 310
Olson, J. E. 400
Onida, F. 420, 430
Opie, R. 400, 310
Ortiz, A. T. 400
Oslund, P. C. 430, 020
Otoole, T. P. 430, 310
Ouellette, C. M. 440, 430
Oum, B. 430, 310
Overturf, S. F. 430, 410
Ozaki, R. S. 400, 100
Ozawa, T. 410, 440
Ozzello, J. 400, 310
Pabst, R. W. 400, 100
Pagoulatos, E. 400, 600
Palmer, D. K. 430, 420
Panagariya, A. 410, 120
Papell, D. H. 430, 310
Pappas, M. 430, 310
Paral, A. K. 410, 440
Parboni, R. 430, 310
Pardo, C. A. 400, 130
Park, H. 400, 720
Parkany, J. 430, 120
Parry, T. G. 440, 600
Pascoe, L. P. 430, 440
Passer, H. C. 430, 130
Patarapanich, W. 410, 320
Patterson, G. 420, 430
Payson, H. 430, 210
Pearson, R. W. 400, 100
Peeters, T. 420, 430
Peffekoven, R. 400, 320
Pelcovits, M. D. 420, 610
Pelkmans, J. L. M. 400, 610
Pelley, A. E. 420, A00
Pelzman, J. 420, 050
Penicaud, J. 440, 500
Pentecost, E. J. 430, 300
Perez, L. L. 400, 110
Petruzzelli, N. M. 400, 440
Pett, G. 400, 210
Pfusterschmid-Hardtenstein, H. K. 400, 000
Phan, D. 420, 130
Phaup, E. D. 430, 310
Philippe, E. A. 400, 030
Phillips, R. J. 430, 310
Philpot, G. A. 400, 210
Pickersgill, G. M. 430, 310
Pickholz, G. R. 430, 310
Piderit, J. J. 410, 430
Piekarz, R. R. 400, 600
Pietta, P. 400
Pincus, J. 440
Pinsky, N. J. 400, 310
Pinto, M. B. 400, 200
Pippenger, J. E. 430, 310
Plaut, S. E. 410, 430
Pliskin, J. 400, 210
Polach, J. G. 440, 110
Polak, J. J. 430, 310
Pollack, G. A. 430, 130
Pollio, G. 430, 310
Pomfret, R. 420, 040
Pooley, S. G. 410, 050
Portz, T. J. 420, 530
Porzecanski, A. C. 430, 120
Powrie, T. L. 400, 720
Pozo, S. 430, 440
Prachowny, M. F. J. 430, 410
Preece, R. 400, 300
Pribram, E. 420, 030
Price, C. H. 440, 610
Price, L. 420, 820
Prindl, A. R. 430, 420
Priovolos, T. 430, 210
Proctor, A. J. 400, 210
Promisel, L. J. 430, 310
Protopapadakis, A. A. 430, 310
Pujol, J. P. 430, 300
Pupphavesa, W. 420, 110
Pursell, G. G. 420, 440
Purvis, D. D. 430, 310
Putnam, B. H. 430, 310
Qureshi, U. A. 410, 060
Rabitsch, E. K. 440, 630
Rabold, R. W. 420, 610
Raff, D. M. 400, 110
Raffer, K. 400, 940
Raines, L. D. 430, 130
Rakowski, J. J. 410, 020
Ralston, J. W. 400, 500
Ramachandran, S. 400, 520
Ramon-Jimenez, J. A. 400, 700
Rapaz, V. J. 400, 310
Raphel, R. L. 440, 110
Rapu, F. I. 400, 500
Rashish, M. 400, 600
Ray, D. P. 400, 100
Ray, E. J. 410, 440
Ray, R. N. 410, 820
Razin, A. 400, 800
Redding, A. D. 440, 110
Regier, H. 430, 210
Reifman, A. 400, 010
Reimann, G. 400, 050
Reimer, R. D. 400, 020
Reinert, E. S. 410, 120
Reinikainen, V. K. 400, 010
Rennhack, R. K. 430, 310
Reynolds, S. E. 410, 120
Rhee, S. S. 410, 320
Rhoads, W. G. 440, 710
Rhomberg, R. R. 430, 210
Rich, G. 430, 310
Richardson, J. D. 430, 420
Richter, J. J. 420, 530
Rieber, W. J. 410, 420
Riedel, J. C. 400, 120
Rietti, M. 440, 060
Riezman, R. G. 410, 420
Rippey, R. S. 400, 310
Roberts, D. L. 430, 110
Robock, S. H. 400, 120
Rock, M. 440, 420
Rodriguez, L. A. 420, 430
Rodriguez, R. M. 430, 310
Roehl, T. W. 420, 630
Rogoff, K. S. 430, 210
Ron, Z. 410, 130
Rondinelli, D. A. 440, 110
Roningen, V. O. 420, 710
Roper, D. E. 430, 210
Rosenberg, M. R. 430, 520
Rosenblatt, S. M. 400, 100
Ross, J. B. 430, 120
Ross, K. 430, 310
Roth, M. M. 420, 050
Rothwell, K. J. 400, 120
Rourke, B. E. 420, 710
Roush, J. L. 440, 120
Roussiang, D. J. 410, 440
Ruff, G. H. 420, 430
Ruffin, R. J. 400, 020
Ruffing, K. G. 430, 110
Rugman, A. M. 440, 430
Ruhl, F. E. 430, 310
Rushing, P. 430, 410
Rutland, J. M. 420, 110
Ryan, R. J. 400, 100
Saboori, F. 430, 310
Sachse, E. Y. 400, 130
Safarian, A. E. 440, 420
Saidi, N. A. 400, 130
Sallors, J. W. 410, 420
Saini, K. G. 400, 120
Salant, M. A. 430, 310
Salant, W. S. 430, 300
Salas Porras, S. E. 410, 510
Salehizadeh, M. 440, 430
Salib, A. B. 400, 120
Salvatore, B. 430, 130
Salvatore, D. 400, 120
Samaras, A. C. 400, 500
Sammons, R. L. 430, 310
Sanders, E. G. 440, 610
Sanderson, F. H. 400, 700
Sanderson, P. P. 440, 520
Sandoval, A. D. 400, 210
Sang, B. 400, 800
Santoro, V. 400, 100
Sapir, H. M. 400, 110
Sarich, B. R. 420, 410
Sarris, A. 400, 100
Sauvant, K. P. 440, 120
Saxe, J. W. 440, 430
Sayad, J. 400
Scaperlanda, A. E. 420, 440
Schembri, L. L. 430, 310
Schiff, F. W. 430, 300
Schilling, D. J. 430, 310
Schlinti, G. 430, 210
Schloss, H. H. 400, 120
Schmid, G. 400, 300
Schmidt, M. 430, 310
Schmidt, W. E. 400, 120
Schmitt, H. O. 430, 440
Schnitzel, P. 430, 520
Schollhammer, H. 400, 600
Schotta, C. 430, 310
Schwartz, N. E. 400, 610
Schwartz, R. H. 430, 110
Scobie, G. M. 400, 710
Scuka, D. 420, 430
Searles, E. W. 410, 010
Sears, T. A. 440, 610
Seawahl, N. 400
Sedjo, R. A. 410, 720
Seidelman, J. E. 400, 000
Seidl, F. T. 420, 820
Sell, A. 400, 100
Seselovsky, E. R. 440, 310
Sgro, P. M. 400, 100
Shadman, M. 430, 120
Shapiro, H. 400, 320
Sharma, J. L. 440, 310
Sharma, N. R. 420, 430
Sheehey, E. J. 420, 120
Sheehy, R. L. 400, 210
Shelburn, M. R. 430, 010
Sherman, H. C. 400, 130
Shibata, H. 400
Shields, R. E. 430, 310
Shin, H. 430, 310
Shinkai, Y. 430
Shinohara, S. 430, 310
Shojai, S. 430, 310
Shone, R. 430, 020
Shouda, Y. 400, 100
Shulman, M. H. 400, 310
Shuman, S. S. 410, 420
Sibert, A. C. 412, 420
Siddiquee, B. A. 430, 310
Sidener, N. L. 400, 120
Siebert, H. 400, 720
Siegel, M. 400, 300
Siegman, C. J. 400, 300
Simmons, A. 400, 100
Simpson, D. J. 400
Sleichter, K. G. 440, 410
Smeal, G. L. 430, 310
Smith, B. A. 430, 520
Smith, G. L. 410, 020
Smolik, J. E. 420, 430
Snape, R. H. 420, 410
Snider, D. A. 430, 410
Soares, F. B. 430, 420
Sodersten, B. 400, 110
Soessatro, H. 440, 110
Soldatos, L. D. 400
Solomon, R. 430, 310
Somanath, V. S. 430, 520
Somensatto, E. 430, 310
Somersan, A. C. 410, 720
Sorensen, P. O. 430, 110
Sotelino, F. B. 400, 610
Southard, F. A. 430, 420
Southworth, C. 420, 920
Spetrini, J. A. 420, 630
Spiegelglas, S. 400, 100
Spingarn, E. D. W. 400, 310
Spiro, B. P. 440, 730
Spitzer, E. G. 430, 440
Sprecs, J. 400, 110
Srinivasan, T. N. 410, 110
Staley, C. E. 400, 030
Stallings, D. A. 430, 310
Stalson, H. 400, 600
Stanley, M. T. 430, 310
Stein, J. P. 400, 020
Steinherr, A. 400
Stekler, L. E. 430, 410
Stephenson, S. M. 410, 420
Stern, R. M. 400, 010
Sternitzke, D. L. 410, 020
Stetting, L. 400, 120
Stevens, G. V. G. 430, 520
Stevens, R. W. 400, 000
Stewart, D. B. 410, 020
Stewart, M. D. 440, 310
Stillson, R. T. 430, 310
Stoecket, A. B. 400, 700
Stollar, A. J. 420, 410
Stone, J. A. 420, 820
Streeb, G. L. 420, 410
Stretch, G. W. 410, 420
Stuart, E. F. 400, 050
Studenmund, A. H. 400, 210
Stuetzel, W. 430, 010
Stukart, G. L. 440, 400
Sullman, M. A. 440
Sullivan, C. K. 420, 320
Sun, E. M. 440, 420
Sun, N. 400, 120
Suomela, J. W. 420, 020
Surh, Y. H. 440
Suris, F. M. 420, 710
Susa, R. P. 400, 110
Suss, E. C. 430, 210
Suvanto, A. 430, 310
Suzuki, T. 400
Svensson, L. E. O. 410, 020
Swanson, P. E. 430, 020
Sydor, L. P. 430, 410
Syvrud, D. E. 400, 300
Szabo, D. 440, 510
Takacs, W. E. 410, 420
Talarico, J. F. 420, 440
Tanaka, H. 430
Taniguchi, I. 400, 720
Tacka, G. M. 420, 130
Teplin, G. B. 430, 210
Tate, E. L. 440
Taubenfeld, R. F. 400, 100
Taylor, W. A. 400, 110
Tellez, F. J. 440, 710
Tempelski, J. 430, 420
Tempel, G. 440
Thackray, L. P. 400, 610
Thanawala, K. 400, 110
Thomas, P. S. 400, 110
Thompson, H. L. 410, 210
Thompson, J. K. 430, 420
Thompson, R. L. 400, 710
Thompson, R. W. 430, 130
Thornblade, J. 430, 440
Thornton, R. M. 430, 210
Thorp, W. L. 400, 110
Thursby, M. C. 430, 410
Tiberi, M. 440, 030
Timmermann, V. E. 400, 310
Tirpak, J. S. 420, 530
Toh, K. 410, 120
Tokar, B. L. 430, 410
Ton-That, T. 400, 300
Torrisi, C. R. 400, 020
Tower, E. 400, 300
Tozier, D. E. 410, 820
Tremblay, R. 400, 300
Truman, E. M. 430, 420
Tryon, R. W. 430
Tsien, S. N. 430, 520
Tsurumi, Y. 400
Tufts, R. W. 420, 720
Tullio, G. 430, 310
Tung, R. L. 410, 510
Turgeon, B. 430, 300
Turner, C. G. 410, 430
Tybout, J. R. 430, 110
Tycon, J. 410, 430
Tzannetakis, G. J. 430, 310
Uehara, H. 400
Ugelow, J. L. 410, 610
Umana, R. 430, 410
Underwood, J. M. 410, 430
Vaghefi, R. 420
Valdepenas, V. B. 420, 310
Valdes, A. 420, 700
Van Den Bulcke, D. G. 400, 440
Van Der Ploeg, S. S. 430, 210
Van Der Spek, P. G. 400, 530
Van Duyne, C. I. 400, 130
Vanneman, T. E. 430, 520
Van Tassel, R. C. 430, 410
Varma, R. 420, 120
Veit, L. A. 400, 100
Vera, F. A. 400, 300
Vernon, R. 440, 420
Vikor, D. 420, 430
Vinas, A. 420, 010
Vittas, H. 430, 310
Volk, R. O. 410, 430
Volmar, G. S. 400, 100
Voss, D. H. 400, 130
Vukmanic, F. G. 400, 600
Wadbrook, W. P. 430, 400
Wadhva, C. D. 400, 100
Wagner, J. 400, 820
Wagner, K. P. 400, 600
Walker, D. O. 400, 120
Walker, F. V. 430, 420
Wall, D. 420, 110
Walter, I. 420, 430
Walters, D. A. 410, 420
Walther, J. V. 430, 310
Walther, T. 430, 310
Wang, G. C. 400, 100
Warner, A. J. 440, 430
Warr, P. G. 420, 110
Wasowski, S. 420, 040
Watanabe, F. 420, 430
Watanabe, T. 410, 430
Waters, A. R. 440, 520
Waters, L. L. 420, 000
Watties, M. D. 410, 850
Weathers, M. W. 420, 310
Webbink, E. S. 430, 420
Wegner, M. 420, 130
Weigel, D. 430, 110
Weil, G. 430, 120
Weiller, K. J. 420, 430
Weinig, D. L. 400, 620
Weintraub, S. 420, 440
Weiser, L. A. 410, 430
Weiss, L. 420, 440
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Wermuth, D. 400
Wert, F. S. 410, 440
Wexler, I. 420, 430
Weymuller, S. B. 400
Wheeler, J. W. 400, 300
Whichard, O. G. 440, 430
Whitman, M. V. N. 430, 420
Whitt, J. A., Jr 400, 300
Wihlborg, C. G. 430, 010
Wilby, W. L. 430, 310
Wiley, J. W. 430, 410
Wilford, D. S. 430, 120
Wilkinson, B. W. 420, 430
Willett, T. D. 400, 300
Willey, H. D. 400, 600
Willgerodt, H. 400
Williams, G. W. 400, 000
Williams, H. R. 400, 100
Williams, J. R. 420, 410
Williams, M. W. 430, 520
Williams, T. M. 430, 130
Williamson, J. 430, 010
Wilson, A. E. 430, 440
Wilson, J. F. 430, 210
Wilson, J. R. 420, 010
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Wittveen, H. J. 430, 130
Woehrling, F. 430, 310
Wolf, B. M. 420, 440
Wolf, M. H. 420, 430
Wolf, T. A. 400, 050
Wolkow, D. D. 400, 100
Wonnacott, P. 400, 320
Wonnacott, R. J. 420, 210
Wood, R. C. 430, 420
Wooding, P. A. 430, 420
Woodland, T. W. 430, 420
Wooton, J. F. 410, 420
Wright, D. J. 400, 720
Wu, P. P. 440, 310
Wyant, F. R. 400, 600
Wymar, B. 420, 120
Wyplosz, C. A. 430, 310
Yafar, E. N. 430, 030
Yahalom, S. Z. 430, 310
Yamada, K. 410, 720
Yankovich, L. 410, 430
Yeh, Y. 410, 430
Yellen, J. L. 400, 130
Yoho, J. G. 420, 720
Yokokawa, K. 400
Yoneda, K. 420, 440
Yoo, J. 410, 110
Young, A. N. 430, 310
Youngelson, H. L. 400, 800
Youssef, S. M. 400, 010
Yu, E. S. H. 410, 940
Yuravlivker, D. E. 400, 120
Zaman, M. R. 430, 520
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Zoh, Y. J. 410, 310
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Zupnick, E. 400, 300

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520 BUSINESS FINANCE AND INVESTMENT
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Ahmad, S. B. 510, 720
Aiken, J. 510, 540
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Alhadeff, A. V. 530, 510
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Allan, P. 510, 010
Allen, B. J. 510, 630
Allen, S. A. 540
Alpern, M. 500, 920
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Ampil, F. L., Jr 520, 540
Amrhein, J. 520, 040
Anderson, A. G. 520, 130
Anderson, B. J. 540, 720
Anderson, E. M. 530
Anderson, P. M. 530, 210
Anderson, U. 540, 510
Anderson, W. O. 520, 310
Andrade, F. J. 520, 320
Andrew, W. P. 520, 310
Andron, M. 520, 010
Arditti, F. D. 520, 000
Arroyo, M. C. 510, 220
Arzac, E. R. 520, 210
Assy, M. R. 520, 310
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Asquith, K. P. 520, 020
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Baker, R. G. 500, 520
Bakken, H. H. 530, 000
Balderston, F. E. 500, 600
Baldwin, C. 520, 610
Bamford, F. E. 520, 210
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Bauerschmidt, A. D. 510, 610
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Beasley, K. W. 500, 600
Beck, P. J. 540
Becker, C. M. 520, 130
Becker, J. W. 530, 210
Becker, W. G. 520, 000
Beebe, W. D. 520, 610
Beetle, G. R. 520, 940
Behling, B. N. 520, 610
Behn, W. H. 520, 820
Belaicazar Lucer, H. H. 520, 630
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Benenson, C. B. 520, 130
Bennett, W. R. 530, 420
Benson, D. E. 520, 310
Benson, P. 530, 210
Berenson, C. 530, 830
Berger, S. 530, 220
Berkowitz, M. S. 520, 510
Berman, N. D. 540, 610
Bernstein, E. H. 520, 220
Bernstein, P. L. 520, 310
Betts, J. W. 520, 010
Betz, R. T. 520, 620
Bhagat, S. 520, 610
Bhattacharya, M. 520, 210
Bicksler, J. L. 520
Bildersee, J. S. 520, 540
Billings, C. D. 520, 320
Bing, R. A. 520, 010
Bingham, T. V. 500, 600
Binkley, H. L. 500, 600
Birkell, J. 530, 400
Black, F. 520, 310
Black, J. B. 520, 310
Blaha, S. 520, 210
Blancato, A. F. 520, 510
Blender, N. E. 520, A00
Blitzstein, M. 510, 630
Bloom, E. 520, 610
Blume, M. E. 520, 310
Bocater, P. F. 520, 610
Bocater, P. F. 520, 610
Bodie, Z. 520, 310
Bohorquez, E. 520, 440
Bollinger, W. L. 520, 940
Bookbinder, A. I. A. 520, 210
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Borchert, F. R. 510, 920
Borins, S. F. 510, 610
Bortz, G. A. 520, 430
Bosch, J. 520, 310
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Bourquard, A. D. 530, 520
Bowman, R. W. 520, 630
Boyce, W. M. 520, 210
Boyle, J. J. 540, 320
Bradford, W. D. 520, 310
Bradham, D. D. 510, 610
Branch, B. S. 520, 610
Brandon, A. O. 520, 600
Brandsel, L. C. 520, 310
Brennan, M. J. 520, 000
Brief, R. P. 540, 220
Brigham, E. F. 520, 610
Bristol, J. H. 510, 310
Broderick, D. G. 540, 520
Brodshatzer, A. 540, 010
Brodt, A. I. 520, 310
Broome, O. W., Jr 520, 540
Brower, G. D. 510, 900
Brown, D. P. 510, 130
Brown, L. D. 520, 540
Brown, P. M. 540, 320
Brown, W. A. 520
Bruner, R. F. 520, 310
Bruns, W. J. 540, 510
Bryson, C. W. 520, 220
Bryson, W. O. 520
Buckwell, L. J., Jr 540, 000
Bunch, C. R. 520, 020
Bunten, J. R. 520, 420
Burgess, F. M. 530, 010
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Burgoon, S. L. 530, 630
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Burman, G. R. 520, 110
Burns, W. L. 520, 310
Burton, J. C. 540, 520
Butler, J. 510, 520
Butterworth, A. V. 530, 520
Caine, W. E. 510, 520
Calderon, M. T. 500, 000
Calhoun, K. M. 520, 630
Callian, V. 520, 630
Camejo, O. 520, 530
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Campbell, T. L. 540, 510
Canziani, A. 500, 130
Caouette, L. 500, 600
Caplan, E. H. 540, 510
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Carey, K. 520, 210
Carleton, W. T. 520, 310
Carlin, E. A. 510, 030
Carlson, J. W. 530, 920
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Carlson, S. C. 510, 850
Carmichael, S. 510, 530
Carpenter, J. C. 520
Carr, H. N. 510, 520
Carrion-Serna, A. 520, 510
Carroll, J. L. 500, 320
Carter, J. A. 520, 510
Caruso, P. J. 500, 060
Casey, R. M. 540, 210
Casson, J. J. 520, 630
Castleman, B. B. 500, 600
Chaganti, R. 510, 530
Chan, J. L. 540, 510
Chan, Y. 520
Chandra, S. 510, 520
Chang, R. C. 540, 210
Chapman, J. F. 520, 130
Charles, R. A. 520, 510
Chatterjee, S. K. 520
Chen, G. K. C. 510, 020
Cheng, P. L. 520, 210
Chia, F. H. 510, 530
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Choi, D. 520, 610
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Christenson, D. D. 500, 510
Christie, G. N. 520, 220
Chung, P. S. 520, 210
Cignarella, V. G. 520, 540
Clam, L. C. 510, 720
Clare, M. T. 520, 210
Clark, G. G. 530, 520
Clark, J. J. 520, 040
Clark, T. A. 520, 310
Clarkson, G. P. 520, 430
Claros, J. C. 510, 400
Clatanoff, K. D. 520, 430
Cleary, E. M. 500, 100
Clements, H. A. 520, 310
Cleveland, F. W. 500, 600
Clewett, R. L. 510, 610
Cochran, P. L. 500, 020
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Cohen, J. B. 520, 400
Cohen, K. J. 520, 310
Cohn, R. A. 520, 000
Cohra, D. J. 520, 610
Colantoni, C. S. 540, 940
Collins, R. A. 520, 210
Comstock, E. G. 530, 510
Conant, R. R. 520, 310
Conklin, G. T. 500, 300
Connor, G. 520, 310
Conrad, D. A. 520, 610
Conrath, D. W. 510
Constantinides, G. M. 520, 020
Conway, V. J. 520, 130
Cook, J. D., Jr 540, 520
Copeland, P. J. 510, 520
Copeland, T. E. 520, 210
Corey, J. M. 500, 610
Corgel, J. B. 520, 930
Cosset, J. 520, 430
Coughlan, J. A. 510, 030
Coughlan, P. B. 520, 540
Couvares, F. G. 530
Cowan, G. R. 510, 930
Cox, R. 530, 920
Cramer, R. H. 520, 210
Crampton, H. E. 520, 540
Crecine, J. P. 510, 320
Crockett, J. H. 520, 610
Croll, R. F. 510, 040
Crosman, A. H. 500, 020
Cummins, J. D. 500, 610
Curatola, A. P. 540
Curnutt, J. H. 520, 510
Curran, P. P. 540, 510
Curran, W. S. 520
Currier, F. P. 530, 220
Curtis, R. T. 520
Czarnecki, G. M. 510, 610
Dahle, R. D. 530, 520
Dale, E. 510, 610
Damaskenides, A. N. 510, 010
Dambrosio, C. A. 520, 940
Damico, M. F. 530, 010
Dangana, A. 520, 310
Daniel, D. L. 520, 310
Darbro, W. G. 520, 210
Darling, J. R. 530, 420
David, J. M. 500, 200
Davidson, J. 520, 540
Davidson, S. 540, 520
Davis, J. V. 520, 510
Davisson, C. N. 530, 610
Deangelo, H. 520
Deangelo, L. E. 540, 610
Deaton, T. H. 520, 610
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Dein, R. C. 540
Deinzer, H. T. 540, 320
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Demichaelis, J. J. 520
Denburg, L. H. 520, 430
Dennis, C. N. 520
Derooy, J. 510, 940
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Diamond, C. J. 520, 310
Dickey, R. W. 510, 520
Dierkes, M. 540, 620
Dietz, P. O. 520, 510
Dillon, R. E. 530
Dimond, C. L. 530, 220
Dinerstein, F. 520
Dinic, C. J. 510, 520
Dittenhafer, B. D. 520, 100
Dittman, D. A. 540, 850
Dixon, D. F. 530, 020
Dizmang, O. K. 540
Do, T. Q. 520
Dobrovolsky, S. 520, 310
Dockeray, J. C. 520, 320
Dodd, P. 520, 540
Doenges, R. C. 520, 040
Domingo, F. B. 540, 520
Domonkos, J. A. 520, 310
Dothan, L. U. 520, 210
Dougall, H. E. 520, 310
Douglas, N. S. 520, 310
Doutt, J. T. 530, 920
Douyon, G. A. 510, 630
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Dowdell, J. M. 530, 220
Downes, D. H. 520, 540
Downs, T. W. 520, 630
Drebin, A. R. 540, 510
Dreiman, L. S. 520, 000
Dudley, C. L. 520, 940
Dulan, H. A. 520, 130
D'Ulli, W. 520, 130
Dumas, B. 520, 430
Duncan, J. L., Jr 520
Duncan, P. W. 520, 000
Dunetz, M. R. 520, 060
Dunford, E. 520, 530
Dunn, K. B. 520, 310
Duparc, B. G. 520, 830
Dwyer, V. A. 510, 520
Dyer, J. C. 520, 130
Earp, M. H. 520, 000
Ebner, M. 520, 130
Eckbo, B. E. 520, 610
Eckert, C. N. 520
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Edwards, R. D. 540, 320
Eggen, D. R. 520, 530
Einhorn, F. F. 540, 510
Eisenberg, B. S. 500, 600
Ekern, S. 520, 210
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Eldridge, D. H. 510, 320
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Elsasser, R. W. 500, 300
El-Turk, G. H. 520, 430
Enks, E. L. 540, 320
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Erdman, H. R. 520, 850
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Feiston, B. 510, 530
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Ferell, R. S. 510, 720
Fernandez-Holman, E. 500
Ferrari, J. R. 520, 020
Fethke, G. C. 510, 020
Fetter, R. P. 530, 630
Fielitz, B. D. 520, 210
Figlewski, S. 520, 130
Finkler, S. A. 540, 910
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Fischer, J. 500, 800
Fischer, M. C. 520, 210
Fisher, L. 520, 210
Flood, D. W. 510, 530
Flynn, D. M. 500, 410
Fogler, R. L. 520
Ford, D. A. 520, 930
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Fowler, M. M. 510, 540
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Francis, J. C., II 520, 310
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Furlong, P. M. 500, 300
Furst, H. 520, 510
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Gaertner, R. C. 520, 210
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Garcia, F. L. 520, 310
Garcia, H. F. 520, 630
Garcia-Echevarri, S. 510, 610
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Gardner, W. H. 510, 010
Garfield, P. J. 520, 630
Gartner, J. 530, 920
Gault, J. R. 510, 810
Geehan, R. R. 520, 220
Gehant, D. C. 510, 000
Gehr, A. K. 520, 310
Geiger, E. P. 510, 410
Geisinger, W. R. 520, 530
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Geske, R. L. 520, 020
Gibbons, M. R. 520, 210
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Giles, D. B. 520, 530
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Gilletta, R. C. 520, 620
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Gindra, A. W. 500, 300
Gitner, G. L. 530, 640
Givens, A. C. 520, 500
Gladwin, T. N. 510, 720
Glassman, S. 500, 520
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Goldberg, M. A. 520, 510
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Goodell, G. S. 520, 310
Goodman, L. S. 520, 430
Goodman, O. R. 520, 610
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Gordon, M. J. 520, 610
Gordon, R. H. 540, 310
Gormley, E. P. 530, 520
Gottlieb, E. 500, 200
Graddy, D. B. 520, 310
Graham, J. J. 510, 920
Graham, P. 520, 000
Graham, S. 520, 010
Greling, D. R. 540, 630

Grambo, R. W. 520, 310
Granger, C. L. 540, 810
Grant, D. 520, 000
Grasser, W. 520
Grassmick, E. R. 520, 000
Grauer, F. L. 520
Grauer, R. R. 520, 000
Green, G. W. 530, 810
Greenburg, R. 530, 720
Greenough, W. C. 520, 100
Greenshields, B. L. 510, 710
Gregor, J. J. J. 500, 000
Gregory, N. 520, 010
Gressis, N. 520
Grether, E. T. 530, 610
Grigg, V. H. 520, 220
Gritzke, M. 510, 520
Grolil, W. 510, 810
Gross, D. 530, 220
Gross, P. W. 500, 400
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Grunberg, E. T. 510, 620
Grygiel, J. A. 530, 510
Guertin, M. A. 520, 030
Gup, B. E. 520, 310
Gupta, K. 520
Gustafson, L. V. 520, 920
Gutenberg, A. W. 510, 630
Guthmann, H. O. 520, 000
Hackett, J. T. 500, 010
Hadad, B. S. 520, 510
Haegele, M. J. 520, 430
Hagerman, R. L. 540, 520
Haimann, T. 510, 000
Haines, G. H. 530, 920
Hakansson, N. H. 520, 540
Hall, C. P. 510, A00
Hallowell, B. C. 510, 310
Halpern, I. 520, 440
Halpern, P. J. 520, 610
Hamada, R. S. 520, 320
Hamm, B. W. 520, 310
Hammarstrom, W. H. 510, 210
Hammer, L. H. 540
Hand, R. J. 510, 610
Hanlon, J. W. 510
Hanson, J. W. 510, 010
Hardin, R. 510, 320
Harpaz, G. 520
Harper, C. P. 520, 300
Harrigan, A. W. 520, 510
Harrington, S. E. 520, 630
Harris, G. T. 520, 310
Harris, R. S. 520, 610
Harris, S. G. 530, 060
Harris, S. L. 510, 130
Harrison, A. J. 530, 420
Harshman, P. 540, 700
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Snyder, R. E. 520, 130
Sobral, B. J. 520, 310
Soden, D. L. 510, 520
Sojoa, L. F. 510, 120
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Solomon, E. 520, 310
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Solverson, L. 530, 610
Sonnino, M. A. 510, 520
Sosnick, S. H. 520, 820
Sotomayor, M. F. 530, 520
Soukup, G. J. 520, 830
Sovereign, M. G. 510, 620
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Spiller, R. 530, 610
Spiro, H. T. 520, 600
Spitz, A. J. 520, 510
Spratlen, T. H. 530, 120
Sproule, R. A. 520, 310
Stabe, M. E. 520, 000
Stalla, R. J. 520, 010
Stainaker, A. C. 510, 000
Stansell, S. R. 520, 210
Stanton, E. J. 520, 130
Starlight, L. L. 520, 720
Starr, R. G. 520, 000
Statman, M. 520, 600
Stein, L. A. 520, 610
Steiner, R. L. 530, 610
Stephens, E. O. 520, 530
Stern, C. 520, 920
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Stewart, W. B. 510, 710
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Stockwell, R. E. 510, 520
Stoelzle, M. 540, 520
Stone, F. 520, 630
Strachan, H. W. 500, 400
Strang, A. I., III 520, 610
Stuhr, D. P. 520, 310
Stulz, R. M. 520, 400
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Subramanian, B. 510, 610
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Sundem, G. L. 540, 520
Suso, J. 520, 110
Sussna, E. 510, 520
Swalwell, G. M. 540
Swanson, E. S. 520, 510
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Switzer, L. N. 520, 620
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Tagliialatela, C., Jr 520, 410
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Talmor, E. 520, 310
Tan, K. 520, 310
Tandon, K. 520, 430
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Taylor, V. W. 540, 020
Teague, A. J. 520, 540
Teesley, H. A., Jr 540, 720
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Tennican, M. L. 500, 600
Tesar, G. 530, 420
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Thayer, T. R. 540, 610
Thiemann, C. L. 510, 520
Thiesel, S. C. 520, 310
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Thrall, N. C. 510
Thrasher, S. C. 520
Tiger, H. M. 510, 030
Tingley, C. N. 520, 530
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Titman, S. 520
Tlapa, G. A. 530, 620
To, M. C. 520, 930
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Tomber, M. W. 520, 320
Topiol, J. 540, 520
Torgerson, M. S. 520, 900
Tovian, E. 500, 530
Treis, J. 520, 310
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Trzcinka, C. 520, 210
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Tway, J. W. 520, 310
Ulin, R. P. 520, 430
Ullman, J. G. 520
Updegraff, D. E. 520, 830
Upson, R. B. 520, 430
Upton, R. M. 520, 610
Url, G. W. 540, 520
Uselton, G. C. 520, 310
Valauri, F. 500
Valdez, M. 520, 110
Van Arsdell, P. M. 520, 540
Vanderweide, J. 520, 610
Van Horne, J. C. 520, 310
Vermaelen, T. 520, 010
Verrue, R. R. 520
Vigen, J. W. 510, 210
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Vinso, J. D. 520, 210
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Voege, H. W. 540, 210
Vogel, T. 540, 510
Vollmers, A. C. 530, 710
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Vora, G. 520, 210
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Wagner, R. C. 520, 710
Wagner, S. R. 510, 810
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Walsh, M. 520, 310
Walsh, P. G. 520, 310
Walsh, R. J. 520
Walter, J. E. 520, 320
Walter, J. T. 530, 210
Walter, R. C. 520, 000
Wang, H. H. F. 520, 210
Ware, W. A. 500, 600
Warga, A. D. 520, 210
Warner, J. 520, 210
Waters, W. R. 520, 920
Watman, W. A. 510, 530
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Weil, L. 520, 310
Weil, R. L. 540, 210
Weingartner, H. M. 520, 210
Weishans, M. T. 520, 310
Wennberg, S. G. 530, 410
Werner, F. M. 520, 310
Wert, J. E. 520, 310
West, S. 520, 530
Westhoff, W. 540, 520
Westphal, D. E. 520, 220
Wetzel, W. E. 520, 540
Whaley, R. E. 520, 210
Wheeler, L. E. 520, 110
Whitaker, G. R. 510, 520
Whitcomb, D. K. 520, 310
White, E. D. 520, 610
White, R. E. 520, 020
White, W. L. 520, 310
Whittington, G. 520, 540
Whittlesey, E. P. 520
Wickey, G. R. 500, 800
Widebac, G. 510, 920
Wiener, E. 540, 010
Wier, P. 520, 610
Wiesenfeld, H. M. 520, 030
Willax, P. A. 520, 110
Williams, A. J. 530, 030
Williams, J. A. 520, 130
Williams, J. B. 520, 310
Williams, J. R. 500, 600
Williams, J. T. 520
Williamson, R. L. 510, 540
Willis, W. J. 530, 000
Willisle, R. H. 520, 720
Wilson, D. P. 500, 600
Wilson, M. 500, 600
Winter, R. A. 520, 610
Wippern, R. F. 520, 000
Wirth, E. D., Jr 530, 510
Withers, W. 520, 440
Witt, R. C. 500, 030
Wolf, M. 530, 430
Wolitzer, P. 540, 520
Wolotkin, P. 500, 540
Wongvasu, V. 530, 420
Woodford, C. W. 510, 520
Woodson, J. D. 530, 420
Woodward, J. T. 520, 210
Wortzel, L. H. 530, 600
Wright, D. R. 530, 630
Wright, H. 510, 220
Wright, L. W. 510, 630
Wu, H. 520, 310
Yamane, J. 520, 130
Yntema, T. O. 520, 130
Young, D. W. 510, 910
Young, F. A. 520, 010
Young, G. G. 530, 610
Young, P. T. 500, 810
Zakon, A. J. 520, 530
Zakon, S. O. 520, 310
Zannetos, Z. S. 510, 630
Zeff, S. A. 540, 520
Zell, S. P. 520, 810
Zeman, M. 500, 200
Zemon, R. 520, 000
Zepp, T. M. 520, 210
Zoffer, H. J. 510, 010
Zukowski, W. H. 520, 510
Zutz, W. 540, 300

600 INDUSTRIAL ORGANIZATION; TECHNOLOGICAL CHANGE; INDUSTRY STUDIES

610 INDUSTRIAL ORGANIZATION AND PUBLIC POLICY
620 ECONOMICS OF TECHNOLOGICAL CHANGE
630 INDUSTRIAL STUDIES
640 ECONOMIC CAPACITY

Adams, J. W. 610, 050
Adams, L. E. 610
Adams, M. F. 610, 720
Adams, W. 610, 630
Adams, W. J. 610, 400
Adelman, M. J. 610, 620
Adler, M. H. 610, 010
Aduddell, R. M. 610, 630
Agthe, D. E. 600, 700
Aislable, C. J. 610, 110
Aitchison, B. 610, 630
Aiade, A. J. 610, 410
Albinsson-Bruhner, N. G. 600
Albrecht, W. P. 610, 910
Alcaly, R. E. 610, 630
Alderfer, E. B. 630, 730
Alexander, A. J. 620, 050
Alexander, S. S. 610, 010
Allal, M. 620, 420
Allan, I. 610, 510
Alleman, J. H. 610, 020
Allen, B. J. 610, 530
Allen, B. T. 610, 630
Allen, R. F. 610, 020
Allen, W. B. 610, 940
Allentuck, J. 610, 110
Almeida, J. 630, 620
Altrogge, P. D. 610, 810
Altvatter, F. E. 610, 320
Amato, L. 610, 620
Amel, D. F. 600, 210
Anderson, G. E. 610, 210
Anderson, K. B. 610, 210
Anderson, K. P. 610, 210
Anderson, T. C. 610, 630
Andrews, W. P. 610, 820
Armour, H. O. 600, 210
Armstong, D. E. 610, 720
Armstrong, G. R. 600, 720
Arnould, R. J. 610, 020
Arterburn, A. B. 610, 630
Asch, P. 610, 020
Auquier, A. A. 610, 410
Ayanian, R. L. 610, 020
Aykac, A. 610, 210
Ayres, R. U. 620, 720
Babe, M. 610, 130
Backhaus, J. 610, 030
Beckman, J. 610, 630
Baden-Fuller, C. W. F. 600, 530
Beer, H. L. 610, 130
Bain, J. S. 600, 720
Baker, A. B. 600, 400
Baker, S. H. 610, 320
Baldwin, J. R. 610, 630
Baldwin, W. L. 610, 630
Ballantine, J. W. 630, 810
Banks, R. L. 630, 930
Banner, P. H. 610, 530
Barber, R. J. 600
Barckley, R. E. 610, 010
Barker, N. H. 610, 720
Barloon, M. J. 630, 940
Barnekov, C. C. 610, 900
Barnes, I. R. 600, 610
Barnicke, W. F. 610, 510
Baron, D. P. 610, 500
Basso, A. J. 610, 630
Batlivala, R. B. D. 610, 630
Battison, E. J. 600, 720
Baughcum, M. A. 610, 710
Baumer, D. L. 610, 710
Beales, J. H. 610, 530
Beattie, D. L. 610, 320
Beatty, B. L. 620, 130
Beauvais, E. C. 610, 210
Beazoglou, T. J. 610, 910
Bechtol, P. T. 610, 810
Beck, R. L. 610, 620
Beckenstein, A. R. 610, 010
Beerbower, J. E. 610, A00
Bell, J. C. 610
Bell, J. P. 610, 640
Bender, J. R. 610, 040
Benham, L. 610, 820
Ben-Ner, A. 630, 050
Bennett, J. D. 630, 720
Berg, H. 610, 030
Berg, S. A. 630, 820
Berg, S. V. 620, 810
Bergendahl, G. H. 610, 910
Berglund, M. F. 630, 610
Berke, L. M. 610, 630
Berkowitz, M. K. 610, 720
Berlin, B. P. 610, 320
Berman, R. A. 600, 320
Bernhardt, I. 600, 000
Berni, D. A. 610, 220
Bernolak, I. 600, 100
Bernstein, J. I. 600, 020
Berry, C. H. 610, 720
Besen, S. M. 600, 300
Bianchi, L. L. 610, 310
Bianchi, P. 610, 050
Biden, D. L. 610, 200
Biederman, H. R. 630, 400
Biederman, P. S. 630, 130
Binswanger, H. P. 620, 710
Bischoff, M. 600, 900
Bisio, A. L. 620, 520
Biswas, T. K. 610, 210
Bittlingmayer, G. 610, 210
Bjuggren, P. 610, 630
Black, G. 600, 100
Blacklock, R. M. 610, 920
Blackstone, E. A. 600, 320
Blair, R. D. 610, 020
Blakley, D. L. 600, 210
Blank, D. M. 630, 130
Blank, U. 610, 940
Blattner, N. 600, 800
Blumenthal, W. 610, 020
Blumner, S. M. 600, 900
Bodily, J. J. 610, 300
Bodisch, G. R. 610, 820
Bodoff, J. 610, 630
Bogar, B. 600, 020
Bohn, R. E. 610, 630
Boles, D. 610, 620
Bond, R. S. 610, 920
Boonin, D. M. 610, 930
Bordman, S. L. 620, 210
Borlaug, K. L. 610, 800
Boske, L. B. 610, 940
Bothwell, J. L. 600, 200
Bowen, J. F. 610, 010
Bower, R. S. 610, 520
Bowes, M. 600, 020
Bowman, G. 600, 500
Boyce, P. 610, 720
Boyd, J. H. 600, 930
Boyer, K. D. 610, 020
Boylan, M. G. 600, 500
Boyle, S. E. 610, 620
Bradburd, R. M. 600, 000
Bradley, J. 610, 320
Braeutigam, R. R. 600, 720
Brandon, B. B. 610, 210
Brandon, P. S. 610, 210
Bratland, J. C. 620, 720
Braunstein, Y. M. 610, 020
Braverman, A. 610, 820
Brennan, T. J. 610, 030
Bresnahan, T. F. 600, 210
Brewer, L. T. 610, 020
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Brock, G. W. 610, 630
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Broemser, G. M. 610, 510
Brogan, R. D. 610, 630
Brooks, W. P. 630, 620
Brown, K. C. 610, 020
Brown, K. D. 600, 800
Brown, R. S. 600, 700
Brozen, Y. 610, 130
Brucker, E. 620, 310
Brue, S. 610, 820
Bruggink, T. H. 610, 200
Bruning, E. 610, 630
Brush, B. C. 610, 630
Bryan, H. G. 610, 300
Bubnys, E. L. 610, 040
Buc, L. G. 610, 630
Buckalew, A. G. 610, 630
Buckles, S. G. 600, 060
Budde, D. E. 610, 210
Bukovsky, A. P. 630, 000
Bumrungcheep, P. 600, 630
Burgess, G. H., Jr 610, 020
Burke, T. R. 600, 800
Burns, L. A. 610, 630
Burns, M. R. 610, 520
Burnside, M. 630, 130
Burrows, J. C. 610, 720
Burton, E. 630, 720
Butler, R. V. 610, 720
Butler, S. E. 610, 020
Ceglarcan, E. 600, 910
Calfee, J. E. 610, A00
Call, D. J. 610, 520
Callinikos, D. N. 620, 110
Camm, F. A. 610, 320
Campbell, T. C. 610, 120
Cantwell, J. R. 610, 940
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Capron, W. M. 610, 620
Cardani, A. M. 610, 620
Carey, R. 610, 320
Carlin, D. J. 630, 520
Carlip, A. B. 610, 020
Carlsson, B. 620, 630
Carman, D. G. 610, 040
Carpenter, J. W. 610, 220
Carr, D. M. 600, 200
Carroll, S. L. 630, 610
Carron, A. S. 610, 310
Carson, C. W. 630, 420
Carter, J. P. 630, 520
Carter, J. R. 610, 020
Carter, W. F. 630, 200
Case, L. S. 600, 020
Cassimatis, P. J. 600, 100
Cavea, R. E. 610, 440
Ceramilac, D. 610, 630
Chamberlain, M. K. 610, 510
Chao, H. 610, 720
Chapman, M. L. 610, 040
Charro, F. d. 630, 920
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Chastek, J. D. 610, 810
Chen, C. 610, 210
Cherry, R. C. 610, 210
Chesler, A. D. 630, 310
Chessler, D. 610, 210
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Chow, G. 610, 530
Christopherson, C. 610, 520
Cicchetti, C. J. 600, 900
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Clark, J. E. 600, 040
Clark, J. P. 630, 720
Clarkson, K. W. 610, 020
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Cocks, D. L. 610, 620
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Cohen, H. A. 610, 900
Cohen, M. A. 610, 320
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Comanor, W. S. 600, 000
Conant, J. L. 600, 800
Conant, M. 610, 630
Conn, R. L. 610, 310
Conners, R. B. 610, 910
Connor, J. M. 630, 440
Conrad, C. 610
Conway, W. B. 610, 820
Cook, A. A. 600, 810
Cook, P. W., Jr 610, 020
Coolsen, F. G. 610, 530
Coelmano, A. J. 600, 800
Costello, P. M. 600, 610
Cotterill, P. G. 600, 800
Coughlan, A. T. 610, 620
Courville, L. 610, 000
Couts, D. A. 600, 940
Cowen, J. 600
Cowing, T. G. 630, 210
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Cox, S. R. 610, 630
Cox, W. A. 600, 100
Crafton, C. G. 610, 210
Craig, A. M. 620, 040
Cramer, C. A. 600, 020
Crandall, R. W. 610, 630
Crane, S. E. 610, 320
Cranswick, H. W. 610, 060
Craven, J. V. 600, 800
Craycraft, J. L. 610, 020
Crew, M. A. 610, 630
Crocker, K. J. 600
Cubbin, J. S. 610, 630
Cullenberg, S. E. 630, 610
Cumming, P. D. 600, 500
Cummings, D. C. 610, 320
Cummings, F. J. 610, 320
Cummins, J. M. 610, 510
Curkendall, S. M. 600, 400
Currie, K. A. 610, 020
Dahl, A. J. 610, 040
Dahl, D. C. 610, 710
Dakin, L. J. 610, 010
Dalton, D. H. 630, 420
Dalton, J. A. 610, 620
Dansby, J. W. 610, 720
Dansby, R. E. 600, 020
Danzon, P. M. 610, 010
Daressa, L. 610, 620
Davidson, R. M. 610, 420
Davies, H. A. 610, 620
Davies, S. W. 610, 620
Davis, P. E. 610, 010
Davis, R. H. 610, 940
Davis, W. B. 630, 720
Day, C. L. 610, 210
Deak, E. J. 610, 020
de Bondt, R. R. 610, 210
Debrock, L. 600
Demsetz, H. 600, 020
de Olden, J. L. 600, 500
De Podwin, H. J. 610, 630
DePue, D. M. 600, 500
Dertouzos, J. N. 610, 820
Desouza, G. R. 630, 520
Deversaux, W. J. 610, 010
Devinney, T. M. 610, 210
Dewees, D. N. 610, 720
Dickson, V. A. 610
Dimopoulos, D. 610, 320
Di Pietro, W. R. 600, 400
Dittmer, R. W. 610, 830
Dobesh, L. 600
Dobrow, P. A. 610, 310
Dobson, D. C. 610, 630
Doctors, S. I. 610, 510
Dodge, J. W. 610, 720
Domike, A. L. 610, 120
Domin, J. S. 620, 520
Donnelly, E. H. 600, 200
Donvito, P. A. 600, 720
Dorman, G. J. 610, 630
Douglas, G. W. 610, 630
Doversberger, R. A. 630, 810
Downing, G. 630, 640
Drake, R. H. 630, 520
Drinkwalter, D. A. 630, 640
Drum, D. S. 610, 310
Duchatelet, M. 610, 020
Duchesneau, T. D. 610, 620
Dudley, W. C. 600, 310
Duetsch, L. L. 610, 630
Duma, D. 600
Dumas, L. J. 620, 010
Dunmore, K. 610
Dunn, J. W. 600, 700
Dunsky, H. 600, 820
Duvall, J. B. 610, 210
Dydo, J. S. 610, 320
Dygert, P. K. 610, 020
Eads, G. C. 610, 620
Eads, L. D. 610, 630
Earley, W. C., Jr 610, 630
Early, A. 610, 010
Easterbrook, F. H. 610, 520
Eastman, S. E. 610, 630
Eboch, E. W. 610, 720
Eckel, C. C. 610, 320
Edge, J. D. 610, 040
Edmonson, N. 640, 630
Edwards, F. R. 610, 310
Edwards, R. P. 610, 010
Egan, J. D. 600, 210
Ehrlich, M. 600, 530
Einhorn, H. A. 610, 630
Eisenstadt, D. M. 610
Eisinger, D. W. 610, 720
Eilas, J. 600, 520
Ellis, R. P. 610, 000
Elnan, H. 610, 630
Elzinga, K. G. 610, 010
Emery, E. D. 610, 910
Englander, A. S. 620, 110
Epple, D. 610, 720
Epstein, B. 610, 630
Epstein, L. 610, 630
Erickson, E. W. 610, 720
Erickson, W. B. 610, 630
Erlenkotter, D. 630, 720
Esposito, F. F. 600, 640
Esposito, L. 610, 910
Estomin, S. L. 610, 720
Esvelt, T. G. 630, 720
Evans, R. D. 600, 940
Ewing, D. R. 610, 620
Fabayo, A. J. 640, 630
Fairris, D. H. 610, 810
Familant, N. 610, 050
Fanara, P. 600, 000
Farley, D. E. 600, A00
Farris, M. T. 610, 630
Faulhaber, G. R. 610, 020
Feigenbaum, A. V. 610, 100
Feigenbaum, S. K. 610, 210
Feinberg, R. M. 610, 820
Feigran, S. D. 610, 420
Feller, I. 620, 040
Felton, J. R. 610, 620
Fenili, R. 610, 630
Fennell, G. H. 630, 610
Ferguson, A. R. 610, 010
Ferguson, J. M. 610, 020
Ferguson, L. 620, 610
Field, J. 630, 800
Finder, A. E. 610, 210
Firestone, F. N. 610, 830
Fisher, A. A. 610, 820
Fitzgerald, V. W. 600, 400
Flaherty, M. T. 610, 620
Flamm, K. S. 600, 400
Flath, D. 610, 020
Foote, J. C. 610, 040
Formby, J. P. 610, 020
Forrest, A. S. 610, 100
Fortenberry, J. E. 610, 620
Fox, J. A. 610, 020
Fraas, A. G. 610, 040
Franco, V. G. 610, 410
Francis, A. I. D. 630, 610
Francis, F. E. 610, 000
Francis, W. J. 610, 910
Francisco, E. W. 610, 630
Frank, H. J. 630, 610
Frank, R. H. 610, 210
Franke, J. F. A. W. 600, 720
Frantz, U. A. 630, 830
Frasca, R. R. 610, 020
Fratter, C. K. 610, 210
Fraumeni, B. M. 620, 630
Fraundorf, K. C. 610, 630
Frederiksen, M. J. 600, 720
Freeland, M. S. 630, 130
French, G. L. 600, 500
Frenster, J. H. 620, 110
Freund, J. L. 630, 310
Frey, N. G. 610, 640
Friedland, C. 600, 010
Friedland, T. S. 610
Friedman, H. 630, 210
Friedman, L. S. 600, 320
Friedman, M. M. 610, 930
Friedman, P. 610, 040
Froehlich, J. W. 630, 010
Frost, N. C., Jr 610
Frucht, P. P. 610, 630
Fulco, L. J. 620, 130
Fuller, D. A. 610, 210
Fuller, J. W. 610, 320
Funkhouser, R. N. 610, 110
Gabel, H. L. 610, 630
Gaffey, J. D. 610, 630
Gagliardi, D. F. 600, 720
Gallagher, D. J. 610, 430
Gallasch, H. F., Jr 630, 920
Galli, T. A. 610, 520
Gal-or, E. 610, 620
Gannon, C. A. 610, 940
Ganale, J. J. 610, 630
Garber, S. G. 610, 210
Gargiulo, G. R. 630, 420
Garvin, D. A. 610, 630
Gaskins, D. W., Jr 610, 720
Gasper, D. 630, 720
Geddes, D. H. 630, 640
Gelb, B. A. 630, 620
Gellman, A. J. 610, 620
Gerber, A. 610, 530

Gerceski, P. A. 600, 800
Gessler, G. A. 610, 210
Ghosh, A. 610, 520
Gibbons, J. C. 610, 210
Gilbert, R. J. 610, 720
Gillan, J. P. 610, 210
Gillen, D. W. 610, 930
Gilmartin, D. 630, 130
Ginsburg, D. H. 610, 310
Giordano, J. N. 610, 320
Gishlick, H. E. 630, 940
Glassman, C. A. 610, 310
Glassman, M. L. 610, 020
Glennie, J. R. 610, 630
Globerman, S. 620, 610
Gobbo, F. 610, 630
Goedde, A. G. 610, 400
Golbe, D. L. 610, 520
Gold, B. 600, 420
Goldberg, J. D. 610, 630
Goldberg, L. G. 610, 310
Goldberg, V. P. 610, 010
Goldenberg, D. I. 630, 110
Goldenthal, A. J. 600, 940
Goldhar, J. D. 620, 630
Goldman, M. B. 610, 020
Goldschmid, M. T. S. 600, 510
Goldstein, J. J. 630, 720
Gollop, F. M. 610, 620
Golub, B. W. 610, 520
Gordon, J. J. 620, 720
Gordon, K. 600, 800
Gordon, S. D. 610, 040
Gorecki, P. K. 610, 630
Gorham, J. E. 620, 110
Gort, M. 610, 620
Goto, A. 600, 020
Gotsias, A. 610, 630
Grabowski, H. G. 610, 620
Graham, W. M. 600, 200
Gramlich, F. W. 610, 320
Granger, T. C. 610, 520
Grant, J. M. 610, 520
Graubard, L. S. 630, 530
Grawe, O. R. 620, 610
Green, C. 610, 820
Green, J. R. 600, 020
Greenberg, W. 610, 900
Greene, J. M. 610, 720
Greenhalgh, P. R. 610
Greenman, J. H. 610, 630
Greenspun, N. 610, 920
Greenwald, W. I. 600, 200
Greenwood, J. 610, 720
Greer, D. F. 610, 310
Gregg, D. E. 610, 420
Grenning, M. R. 610, 720
Griffin, J. M. 610, 210
Griparud, G. 630, 530
Grosaman, P. J. 610, 930
Gruber, W. H. 600, 500
Gruenspecht, H. K. 610, 720
Grunewald, D. 610, 520
Grygiel, F. S. 610, 320
Guasch, J. L. 610, 820
Guerin-Calvert, M. E. 610
Gunn, J. R. 610, 440
Gurley, Y. 630, 320
Gutmann, P. 600, 100
Habr, D. S. 610
Haddock, D. D. 610, 040
Hadley, E. M. 610, 420
Haendler, T. 610, 710
Halbrook, S. A. 610, 700
Hale, R. D. 600, 930
Hall, G. R. 610, 620
Hall, T. W. 630, 210
Halteman, J. 610, 020
Hamilton, J. L. 610, 630
Hammond, C. J. 600, 020
Hannan, T. H. 600, 900
Hansen, J. A. 610, 630
Hansen, R. W. 600, 020
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Harbeson, R. W. 610, 020
Hardy, D. L. 600, 630
Haring, J. E. 610, 210
Haring, J. R. 610, 010
Harlan, K. M. 610
Harman, A. J. 610, 620
Harper, D. V. 610, 530
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Harris, J. E. 610, 910
Harris, L. E. 610, 520
Harris, R. G. 610, 630
Harrison, R. L., Jr 610, 630
Hartline, J. C. 630, 310
Hartzmark, M. L. 610, 320
Haworth, C. T. 600, 820
Hay, G. A. 600, 610
Haymes, A. D. 610, 320
Hazledine, T. J. 610, 130
Helm, P. 630, A00
Heiney, J. N. 610, 820
Heilman, R. 610, 940
Helms, R. B. 610, 620
Helmuth, J. A. 610, 630
Hemenway, D. 610, 910
Henderson, J. S. 610, 320
Hennigan, J. F., Jr 610, 940
Hershenhorn, L. L. 610, 320
Hertzfeld, H. R. 600, 940
Hession, C. H. 610, 040
Heusa, E. T. 610, 110
Hewins, D. C. 600, 020
Higinbotham, H. N. 630, 520
Hilke, J. C. 610, 320
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Hill, E. W. 610
Hill, L. J. 610, 720
Hill, R. D. 600, 300
Hiller, J. R. 600, 800
Hilton, G. W. 610, 830
Hinch, M. J. 610, 210
Hines, H. H. 600, 300
Hirschey, M. 610, 510
Hjorth-Andersen, C. 600, 720
Hochman, E. 600, 700
Hodge, J. H. 600, 940
Hoffer, G. E. 610, 920
Hoffmann, W. 630, 720
Hokanson, J. R. 610, 510
Hollander, A. J. 610, 400
Hollas, D. R. 610, 630
Holley, H. L. 630, 220
Holman, M. A. 620, 720
Holmberg, S. R. 610, 510
Holmes, A. S. 610, 720
Holmes, R. R. 610, 010
Holstein, E. J. 610, 030
Holton, R. H. 610, 530
Honig, S. 610, 310
Hoppmann, E. 610, 050
Horn, K. N. 630, 610
Horstmann, I. J. 610, 020
Hostetler, W. L. 600, 100
Hotelling, H., Jr 610, A00
Houston, D. A. 610, 920
Howard, M. C. 610, 630
Howe, E. T. 610, 830
Howes, C. 630, 940
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Hoyt, D. R. 610, 830
Huber, P. B. 610, 040
Huettner, D. A. 600, 210
Hughes, W. R. 610, 630
Hunter, J. E. 610, 020
Hurdle, J. A. 610, 320
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Hymson, E. B. 600, 130
Igo, D. J. 600, 720
Ilacqua, J. A. 610, 020
Ileo, M. J. 610, 520
Illig, D. C. 610, 720
Ippolito, R. A. 610, 820
Isbister, C. M. 610, 110
Isely, E. K. 630, 720
Ishii, S. 610, 720
Ishii, Y. Y. 610, 710
Iulo, W. 630, 720
Jackson, R. 610, 520
Jacobs, E. A. 600, 720
Jacobson, I. B. 600, 500
Jacobson, J. E. 620, 720
Jacquemin, A. P. 610, 620
Jadlow, J. M. 610, 620
Jaffee, B. L. 610, 930
Jameson, M. H. 610, 210
Janus, M. E. 630, 030
Jarrell, G. 610, 520
Jarrett, J. P. 610, 400
Jeffries, C. N. 610, 720
Jenkins, A. W. 610, 810
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Jensen, H. C. 600, 700
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Jensen, O. W. 600, 400
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Jones, D. L. 630, 610
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Jones, R. O. 610, 720
Jordan, W. A. 610, 630
Joskow, P. L. 610, 010
Jurewitz, J. L. 610, 720
Kafandaris, S. 600, 100
Kahal, M. 610, 720
Kahn, A. E. 610, 630
Kahn, M. H. 610, 720
Kalifa-Assad, S. 630, 210
Kalindaga, Y. C. 610, 110
Kalmbach, P. 620, 800
Kamerschen, D. R. 600, 020
Kamlet, M. S. 610, 210
Kampmeier, R. A. 620, 120
Kampe, W. E. 610, 320
Kane, J. A. 600, 900
Kaplan, D. P. 610, 320
Kardasz, S. W. 600, 000
Karels, G. V. 610, 020
Karlson, S. H. 610, 020
Kaserman, D. L. 610, 930
Kass, D. I. 610, 520
Kassing, D. B. 610, 820
Katz, H. 630, 610
Kaysen, C. 600, 000
Keck, O. 610, 620
Keeler, T. E. 610, 630
Kelley, A. D. 610, 630
Kelly, J. R. 610, 720
Kelly, K. 620, 020
Kelly, W. H. 600, 300
Kelton, C. M. L. 610, 930
Kemp, B. A. 610, 020
Kemper, P. 610, 810
Kempf, D. G., Jr 610
Kendrick, M. J. 610, 720
Kenison, A. 610, 210
Kennedy, J. L. 610, 620
Kepner, J. W. 610, 320
Kerby, W. C. 610, 320
Kerr, W. O. 600, 800
Kessler, M. D. 630, 940
Keston, T. R. 610, 020
Keyes, L. S. 610, 020
Khalilzadeh-Shirazi, J. 610, 110
Kimble, W. J. 600, 020
Kimmel, S. 610, 710
King, D. M. 630, 720
King, M. J. 610, 720
Kinory, S. 600, 800
Kirby, F. C. 610, 630
Kirman, W. 610, 010
Kirsch, L. D. 610, 720
Kitch, E. W. 610
Kitt, H. P. 600, 040
Kitti, C. E. 620, 420
Klein, B. 610, 020
Klein, J. D. 610, 720
Klein, S. E. 610, 200
Klepper, S. I. 610, 210
Knox, R. L. 610, 630
Kobrin, P. R. 610, 720
Koch, J. V. 610, 850
Kochin, L. A. 610, 320
Kolb, J. A. 610
Kolsky, R. I. 610, 620
Konakyasma, A. 620, 110
Kopp, T. J. 610, 720
Koppenhaver, G. D. 610, 310
Kottke, J. R. 610, 630
Koumatos, G. D. 610, 400
Kraus, J. 600, 210
Kriebel, W. R. 630, 710
Kroes, R. J. 600, 500
Krouse, C. G. 600, 520
Kruker, M. 610, 110
Krzewicka, B. 600, 400
Kuhlman, J. M. 610
Kushner, J. 610, 810
Kwerel, E. R. 610, 320
Kwoka, J. E. 610, 630
Kyle, R. 610, 020
Kyriacou, L. 600, A00
Laband, D. N. 610, 020
Labombard, B. M. 600, 500
Lackey, C. W. 610, 430
Lackman, C. L. 620, 530
Laderouta, C. D. 610, 520
Lafferty, R. N. 610, 930
Lago, A. M. 610, 630
Lahiri, S. 630, 210
Lahm, H. G. 630, 010
Lamberton, D. M. 620, 020
Lampert, M. H. 610, 010
Lancaster, A. A. 610, 630
Landes, W. M. 610, 010
Landon, J. H. 610, 630
Lane, W. J. 610, 020
Langenfeld, J. 610, 020
Lanning, S. G. 610, 210
Lanzilla, E. E. 630, 540
Lanzillotti, R. F. 610, 130
Lapinsky, M. 610, 210
Larner, R. J. 610, 620
Larson, T. E. 610, 820
Latham, R. J. 610, 910
Latour, M. 620, 540
Lawrence, R. J. 610, 520
Lawson, E. 610, 920
Lawson, R. S. 600, 800
Lazar, F. 610, 410
Leahy, A. S. 610, 850
Lean, D. F. 600
Lee, T. K. 600, 020
Leeson, K. W. 600, 400
Lefever, J. T. 610, 210
Leffler, K. B. 610, 920
Leibowitz, D. 610, 510
Leibowitz, W. 610, 530
Leininger, W. J. 620, 020
Lemelin, A. 600, 210
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Lenchek, G. 630, 520
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Lerman, F. D. 610, 210
Leveson, S. M. 600, 520
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Levin, S. L. 610, 600
Levin, T. H. 610, 630
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Levinson, S. B. 610, 020
Leviton, E. B. 610, 310
Levonian, M. E. 610, 820
Lewis, C. 600, 210
Liebowitz, S. J. 600, 010
Likens, J. D. 600, 910
Lindahl, M. L. 610, 630
Lindsay, D. S. 610, 020
Link, A. N. 620, 610
Linneman, P. D. 610, 930
Lipsky, A. B. 600
Lissak, R. S. 600, 100
Litan, R. E. 610, 720
Littlechild, S. C. 610, 020
Litvak, I. A. 600, 400
Liu, V. W. 610, 020
Llorens-Urrutia, J. L. 630, 940
Lobo, F. 600, 110
Locklin, D. P. 610, 000
Loescher, S. M. 610, 630
Lofthouse, S. 610, 630
Long, W. F. 610, 210
Long, W. F. E. 610, 630
Long, W. H. 610, 940
Loosmore, R. J. 610, 400
Lorant, J. H. 610, A00
Lovett, W. A. 610, 300
Lowenthal, M. E. 610
Loyd, J. L. 600, 200
Lucas, R. L. 630, 710
Ludlum, M. D. 630, 500
Lunn, J. E. 610, 620
Luski, I. 610, 920
Lustgarten, S. 610, 520
Macchia, A. 600, 500
MacDonald, J. M. 610, 820
MacNeal, E. 630, 510
MacReynolds, W. K. 610, 020
Maddigan, R. 610, 720
Madlan, A. L. 610, 120
Magat, W. A. 610, 620
Magura, M. 600, 020
Maher, M. D. 610, 720
Malko, J. R. 610, 630
Mancke, R. B. 610, 720
Mangano, C. A. 630, 720
Maniatis, G. C. 610, 110
Mann, H. M. 610, 630
Mansfield, E. 620, 210
Mansoor, Y. M. 610, 900
Marchesaault, T. E. 630, 900
Marchetti, P. K. 610, 320
Marfels, C. T. 610, 630
Margolis, S. E. 610, 930
Marion, B. W. 610, 530
Markham, J. W. 610, 010
Marsh, C. F. 610, 510
Marshall, R. W. 610, 310
Marshalls, R. A. 600, 720
Martel, A. H. 610, 820
Martin, D. D. 600, 420
Martin, L. R. 610, 210
Martin, S. 610, 020
Marvel, H. P. 610, 810
Marx, T. G. 610, 630
Mason, T. W. 610, 720
Masson, A. 610, 710
Masson, R. T. 610, 010
Mastan, S. E. 610, 050
Mastri, T. F. 630, 520
Mather, N. W. 610, 720
Mattar, H. 630, 520
Matthews, J. O. 600, 320
Maule, C. J. 610, 440
Maurer, F. 610, 310
Max, P. 610, 630
May, J. J. 610, 910
Mayer, C. P. 610, 520
Mayo, J. W. 610, 720
McBride, M. E. 610, 210
McCall, C. W. 610, 630
McClements, L. D. 610, 910
McColm, G. T. 620
McConnaughey, J. S. 630, 900
McConnaughey, J. W. 610, 620
McCormick, C. A. 600, 320
McCoy, F. L. 610, 210
McDermott, J. J. 620, 030
McDevitt, P. K. 630, 720
McDonald, S. L. 630, 310
McEachron, N. B. 630, 620
McElroy, K. M. 610, A00
McFarland, H. 600, 420
McGee, J. S. 610, 020
McGuckin, R. H. 610, 210
McGuire, T. G. 610, 020
McKie, J. W. 610, 630
McLain, J. J. 630, 930
McLean, R. S. 610, 630
McMahon, J. A. 610, 630
McMullen, B. S. 610, 300
McNicol, D. L. 600, 210
McQueen, D. L. 610, 010
Mead, D. E. 600, 200
Mead, W. J. 610, 720
Meehan, J. W. 610, 630
Mehta, S. D. 600, 520
Melody, W. H. 610, 110
Melton, L. J. 610, 040
Meltzer, J. J. 600, 030
Menge, J. A. 610, 320
Mennemeyer, S. T. 610, 910
Mensinkai, S. S. 630, 020
Merchant, S. M. 610, 010
Mercier, A. R. 610
Merewitz, L. 610, 210
Merrifield, D. E. 630, 310
Messier, M. E. 610, 000
Mietus, J. D. 610, 720
Miklius, W. 630, 710
Miller, E. M. 610, 520
Miller, E. S. 600, 000
Miller, G. M. 610, 020
Miller, I. M. 610, 010
Miller, J. C. 610, 420
Miller, R. A. 610, 630
Miller, R. E. 610, 220
Millsaps, S. W. 610, 720
Mitchell, B. M. 610, 210
Mitchell, R. W. 630, 210
Miura, T. 600, 510
Modlin, G. M. 610, 040
Molhuysen, P. C. 600, 800
Mongoven, J. F. 610, 630
Monteverde, K. A. 610
Montgomery, H. 620, 720
Moore, S. F. 610, 630
Moore, T. G. 610, 630
Moorman, G. B. 620, 920
Morefield, R. D. 600, 820
Moretta, R. S. 610, 940
Morgan, C. H. 610, 820
Morgan, H. E. 620, 610
Morgan, J. D. 630, 010
Morkre, M. E. 610, 420
Morris, C. E. 610, 030
Morris, J. A. 610, 130
Morrison, S. A. 610, 210
Morrissey, G. R. 630, 130
Morrow, J. W. 610, 000
Morse, D. E. 610
Morse, H. C. 610, 630
Morse, R. 600, 400
Mosteller, G. 610
Mota, L. R. 610, 310
Mueller, D. C. 610, 020
Mueller, W. F. 610, 630
Muir, A. H. 600, 200
Mukhopadhyay, A. K. 600, 100
Mulee, A. M. 610, 720
Mulholland, J. P. 600, 720
Muller, R. A. 610, 720
Mulligan, J. G. 600
Mullin, G. E. 610, 130
Munro, J. M. 610, 940
Munson, M. W. 610, 320
Munyon, P. G. 610, 040
Murall, R. 610, 120
Muskin, J. B. 630, 930
Myers, J. G. 630, 210
Mysliinski, W. C. 610, 320
Nacini, G. 630, 810
Nakao, T. 610, 020
Nalezzkiewicz, W. 600, 400
Narver, J. C. 610, 530
Nauta, J. 620, 520
Neary, H. M. 610, 050
Needham, D. 610, 300
Needy, C. W. 610, 320
Neel, R. E. 610, 030
Neill, C. P. 610, 720
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Nelson, B. L. 610, 210
Nelson, E. L. 600, 720
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Nelson, P. A. 600, 720
Nelson, P. B. 600, 400
Nelson, P. E. 610, 910
Nelson, R. A. 610, 620

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Nelson, R. L. 610, 520
Nemetz, P. N. 610, 720
Netter, J. M. 610, 630
Neuner, E. J. 610, 720
Neustein, S. 600, 800
Newmark, C. M. 610, 020
Nichols, A. L. 610, 720
Nichols, L. M. 610, 130
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Nicholson, P. R. 610, 630
Nicol, D. J. 600, 520
Nierenberg, R. A. 610, 720
Nightingale, E. A. 610, 710
Nilson, W. G. 600, 000
Nishimizu, M. 600, 110
Noe, G. A. 610, 630
Noether, M. G. 610, 520
Nomikos, G. E. 630, 810
Norling, N. M. 610, 720
Norman, D. A. 610, 020
Norton, E. A., Jr 610, 310
Nowotny, K. R. 610, 110
Oberender, P. O. 630, 400
Ocasio, W. C. 600, 930
O'Connell, D. W. 610, 310
O'Connor, K. J. 600, A00
O'Connor, T. 610, 520
Ogata, T. 610, 030
Ogur, J. D. 610, 630
O'Hara, T. E. 630, 620
Oliver, L. E. 610, 630
Oliver, W. J. 600, 100
Olley, R. E. 630, 040
Olson, C. E. 610, 520
Olson, J. R. G. 630, 520
Olson, R. E. 610, 520
Olszowski, R. 610, 630
O'Neill, D. C. 600, 200
Ornstein, S. I. 610, 630
Orren, L. H. 610, 630
Osher, K. R. 610, 520
Oster, S. M. 610, 920
Overstreet, T. R., Jr 610, 020
Owen, B. M. 610, 000
Ozanne, T. O. 610, 720
Pacey, P. L. 610, 020
Pachauri, R. K. 610, 720
Palley, J. P. 630, 610
Palmer, J. P. 600
Panzar, J. C. 610, 020
Pardey, P. G. 620, 710
Parikh, A. 620, 820
Park, R. 610, 030
Parker, R. C. 610, 630
Parrish, G. O. 610, 630
Parsons, S. G. 610, 720
Parzych, K. M. 610, 420
Pashek, R. D. 610, 630
Pashigian, B. P. 610, 020
Paszkiewicz, R. G. 610, 720
Patry, M. 610, 510
Payne, J. P. 630, 610
Pazderka, B. 610, 010
Pearce, A. 610, 420
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Peckham, B. W. 610, 040
Pegrum, D. F. 600, 020
Peirce, W. S. 620, 320
Peltzman, S. 610, 020
Penland, G. P. 610, 210
Penn, D. W. 610, 720
Penn, W. M. 610, 310
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Perkins, W. C. 610, 310
Peries, B. M. 620, 220
Perlman, N. 630, 420
Perrakis, S. 610, 520
Perry, M. K. 610, 630
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Petersen, W. M. 610, 630
Peterson, F. M. 630, 210
Peterson, R. D. 610, 020
Peterson, T. C. 610, 020
Phelan, J. J. 610, 920
Phelps, C. E. 600, 900
Phillips, A. 610, 620
Phillips, C. F., Jr 610, 630
Phillips, L. T. 600, 400
Phillips, O. R. 610, 630
Pierce, A. E. 630, 530
Pietta, M. J. 610, 720
Pikrallidas, C. E. 610, 920
Pindyck, R. S. 610, 210
Pinkston, E. A. 610, 630
Pisarkiewicz, J., Jr 610, 210
Pitcher-Eisenberg, J. M. 610, 020
Plesko, G. A. 600, 900
Plotkin, I. H. 610, 520
Plummer, J. L. 610, 720
Polak, G. 620, 310
Pontney, J. A. 610, 020
Porter, M. E. 610, 500
Porter, R. H. 610, 210
Post, G. R. 600, 510
Pottle, J. T. 630, 840
Powell, D. O. 600, 000
Preston, L. E. 610, 530
Price, F. R. 630, 210
Priest, W. C. 620, 920
Primeaux, W. J. 610, 510
Prince, B. L. 610, 020
Prodi, R. 610, 630
Pronk, R. T. 600, 400
Prosi, G. 600, 050
Pugel, T. A. 610, 420
Pulsifer, R. 600, 100
Pustay, M. W. 610, 420
Qualls, P. D. 610, 010
Quinn, K. 610, 300
Raab, R. L. 610, 720
Radell, W. W. 610, 320
Radisch, L. J. 610, 800
Randall, R. L. 610, 630
Rapoport, J. 620, 630
Rapp, R. T. 610, 040
Rappaport, E. 600, 840
Rasmussen, E. F. 610, 310
Rattey, R. L. 610, 520
Rawle, C. C. 620, 630
Reagan, P. 610, 320
Reck, R. O. 610, 020
Reddy, N. N. 600, 720
Reed, S. F. A. 610, 620
Reekie, W. D. 630, 610
Rehmet, P. O. 630, 130
Reilly, W. R. 610, 710
Reinertsen, P. J. 630, 420
Reitman, F. 610, 720
Renaud, F. 610, 620
Reschenthaler, G. B. 610, 530
Reuter, P. 610, 830
Reynolds, R. J. 610, 010
Reynolds, W. A. 610, 310
Rhoades, S. A. 610, 310
Rice, E. M. 610, 520
Richards, R. J. 610, 720
Rizzo, M. J. 610, 020
Roark, A. D. 610, 210
Roberts, M. J. 610, 120
Roberts, M. J. 620, 610
Roberts, T. 610, 710
Robertson, R. A. 610, 010
Robeson, F. E. 610, 520
Robinson, E. A. 630, 220
Robinson, M. E. 630, 530
Rochlin, C. B. 610, 130
Rockwood, A. D. 610, 720
Rodgers, J. F. 610, 320
Rodgers, J. M. 630, 320
Roessel, C. S. 610, 010
Rogers, H. B. 630, 610
Rogers, J. S. 620, 210
Rogers, R. P. 630, 610
Rolfe, R. S. 610, 630
Romeo, A. A. 620, 610
Romine, C. A. 630, 530
Rosegger, G. 620, 420
Rosenberg, J. B. 630, 610
Rosenberg, L. C. 600, 420
Rosenbluth, G. 610, 130
Rosendahl, E. E. 630, 120
Rosenfield, A. M. 600, 610
Rosenthal, A. J. 600, 200
Ross, D. N. 620, 840
Ross, T. W. 610, 020
Rossetti, M. A. 610, 630
Rothman, M. P. 630, 610
Rousche, L. R. 610, 000
Round, D. K. 610, 630
Roush, C. T. 610, 720
Routledge, J. A. 610, 500
Roy, R. T. 630, 130
Roza, S. E. 640, 610
Rubin, L. S. 610, 210
Russell, M. 630, 720
Ryden, B. 610, 130
Sabatino, R. A. 610
Saft, L. 610, 630
Salinger, M. A. 610, 320
Saloner, G. 610, 020
Salop, S. C. 610, 920
Saltzman, H. E. 610, 920
Sampson, R. J. 610, 010
Sander, D. E. 630, 110
Sandler, R. D. 610, 720
Sapinsley, J. M. 610, 010
Sappington, D. 610, 020
Sarkar, A. K. 600, 530
Sattler, E. L. 610, 630
Saunders, R. S. 610, 110
Saunders, R. S. 610, 430
Savolan, R. T. 610, 920
Sawyer, J. R. 610, 320
Scale, E. 610, 120
Scaramucci, J. A. 610, 110
Schaefer, E. J. 610, 520
Schap, D. J. 600, 200
Schary, P. B. 610, 530
Scheer, R. M. 610, 510
Scheirer, W. K. 620, 610
Schenker, E. 610, 930
Scherage, C. A. 610, 620
Scherer, F. M. 600, 020
Schifrin, L. G. 610, 920
Schmalensee, R. L. 610, 020
Schmidt, M. 610, 520
Schmit, G. 610, 320
Schnabel, M. 610, 620
Schneider, C. G. 630, 940
Schneider, L. 610
Schotsman, G. J. 600, 300
Schroder, F. J. 610, 310
Schroeter, J. R. 610, 210
Schuette, H. L. 610, 510
Schumaier, C. P. 620, 630
Schupack, M. B. 610, 720
Schuttinga, J. A. 630, 210
Schwalbach, J. 600, 520
Schwartz, C. H. 610, 920
Schwartz, H. H. 600, 120
Schwartz, L. B. 610, 210
Schwartz, M. 610, 310
Schwartz, N. L. 620, 610
Schwartzman, D. 610, 620
Schwarz, P. M. 610, 320
Schweitzer, S. O. 630, 210
Schwindt, R. 610, 630
Schwinn, C. R. 600, 210
Scott, F. A. 610, 210
Scott, J. T. 610, 310
Scott, W. L. 610, 520
Seddon, V. K. M. 630
Seeto, D. G. 610, 420
Segerstrom, P. S. 610, 210
Seldon, Z. A. 610, 830
Sell, J. W. 610, 520
Sen, K. C. 610, 120
Seneca, R. S. 610, 010
Seplaki, L. 610, 050
Setzer, F. O. 610, 910
Shannon, J. 610, 320
Shackett, J. R. 610, 810
Shaffer, E. H. 610, 420
Shages, J. D. 610, 720
Shapiro, A. 610, 720
Shapiro, D. M. 600, 050
Sharp, M. L. 610, 910
Shaw, R. E. 610, 630
Shen, T. Y. 600, 110
Shepard, L. E. 610, 920
Shepherd, P. L. 630, 440
Shepherd, W. G. 600, 010
Sherman, R. 610, A00
Shipman, W. D. 610, 040
Shriner, R. D. 630, 940
Shughart, W. F. 610, 020
Shuldiner, R. 610, 020
Sichel, W. 610, 630
Sichter, J. W. 610, 510
Siddayao, C. M. 600, 400
Sider, H. 600, 800
Sidhu, S. S. 620, 710
Siegfried, J. J. 610, 060
Silberman, S. D. 610, 630
Silberston, Z. A. 610, 630
Silkman, R. H. 620, 320
Silva, D. 600, 110
Silversin, L. 610, 320
Silvia, L. 610, 630
Simon, C. J. 610, 520
Simunic, D. A. 610, 630
Sisk, D. E. 610, 020
Skancke, S. L. 610, 720
Slesinger, R. E. 600, 900
Sletmo, G. K. 610, 630
Sloss, J. 610, 600
Smiley, A. K. 610, 520
Smiley, R. 610, 720
Smith, A. J. R. 600, 100
Smith, D. D. 610, 630
Smith, D. E. 630, 920
Smith, D. K. 610, 630
Smith, D. S. 610, 630
Smith, F. A. 610, 720
Smith, J. A., Jr 610, 530
Smith, J. K. 610, 010
Smith, J. L. 610
Smith, M. A. 600, 210
Smith, R. E. 610, 630
Smith, T. C. 610, 210
Smithson, C. W. 600, 720
Smukler, P. R. 630, 810
Snapp, B. R. 610, 020
Sobin, B. 610, 630
Sobotka, S. 610, 820
Soladay, J. J. 600, 720
Sole, F. 600, 940
Solo, R. A. 610, 620
Soma, J. T. 610, 620
Sommers, P. E. 610, 720
Sonda, J. D. 600, 020
Sonny, J. 600, 200
Sparling, L. I. 610, 210
Spavins, T. C. 600, 320
Spencer, F. A. 620, 830
Spencer, M. H. 610, 630
Spiller, P. T. 610, 020
Springer, R. F. 600, 800
Spychalski, J. C. 600, 500
Staiou, C. G. 610, 130
Stangle, B. E. 600, 520
Stanley, K. B. 610, 630
Stearns, R. N. 630, 020
Stegemann, K. 600, 420
Stein, B. A. 610, 110
Steiner, I. M. 610, 020
Stevenson, R. E. 610, 210
Stewart, J. F. 610, 520
Stewart, M. D. 610, 420
Stillman, R. S. 600, 210
St Marie, S. M. 610, 630
Stoller, M. A. 610, 630
Stone, B. M. 600, 210
Stonebraker, R. J. 610, 130
Story, H. J. 600, 930
Stotter, J. S. 630, 130
Strack, W. D. 610, 020
Stram, B. 610, 320
Strand, S. H. 610, 110
Strassmann, D. L. 610, 320
Strein, C. T. 630, 940
Streiter, S. H. 600, 700
Strickland, A. D. 610, 630
Stumpp, M. S. 630, 610
Sudit, E. F. 620, 540
Suelflow, J. E. 630, 540
Sufrin, S. C. 610, 510
Sugiyama, S. O. 610, 020
Sumrall, J. B., Jr 610, 210
Svelkauskas, L. A. 620, 120
Svorny, S. V. 610
Swaffar, J. L. 610, 320
Swaine, H. R. 610, 320
Swanson, E. V. 610, 210
Swenson, G. G. 600
Sykes, A. O. 610, 020
Szatrowski, Z. Z. 620, 200
Szerszen, C. A. 610, 830
Taff, C. A. 600, 530
Talley, C. A. 630, 940
Tandon, P. 620, 020
Tansey, M. M. 600, 400
Tapon, F. 600, 020
Tarpley, F. A. 620, 610
Taschdjian, M. G. 600, 720
Tassey, G. C. 620, 610
Taube, R. K. 610, 310
Taylor, G. T. C. 610, 720
Taylor, T. N. 610, 910
Teece, D. J. 610, 620
Tenenbaum, B. W. 600, 320
Tepel, R. C. 610, 210
Teper, L. 630, 220
Tereshtenko, V. J. 610, 710
Teunissen, S. W. 610, 520
Thakur, M. 610, 630
Thibodeau, R. E. 610, 630
Thomas, C. R. 610, 720
Thompson, M. 610
Thompson, R. S. 610, 510
Thompson, S. J. 610, 030
Thorning, M. M. 630, 220
Thorpe, K. E. 630, 620
Thorpe, R. S. 600, 610
Tiemann, T. K. 610, 520
Tigadi, C. B. 610, 000
Tighe, M. E. 600, 210
Tillett, A. D. 600, 000
Ting, H. M. 610, 500
Tingleff, J. R. 610, 210
Todd, A. W. 610, 630
Todd, J. D. 610, 520
Tomer, J. F. 620, 310
Tomsick, R. D. 610, 520
Towers, R. G. 630, 520
Tracy, J. 610, 820
Trainor, J. F. 610, 630
Traponi, J. M. 610, 210
Trebing, H. M. 610, 630
Trigg, C. T. 620, 630
Tromp, E. D. 610, 420
Trozzo, C. L. 610, 720
Tschirhart, J. T. 610, 020
Tsukahara, T. 630, 520
Tuck, C. C. 610, 520
Twight, C. 610, 320
Tye, W. B. 610, 630
Tyler, T. P. 610, 820
Uhler, R. G. 610, 520
Uitermark, P. J. 610, 050
Upson, B. T. 610, 830
Valencia, J. M. 630, 210
Valtri, D. L. 610, 620
Van Auken, K. G. 610, A00
Van Dewater, J. 630, 210
Ventura, J. S. 610, 020
Vernon, J. M. 600, 020
Viton, P. A. 610, 020
Vlahakis, M. C. 600, 020
Vogel, W. B. 600, 020
Vogelsang, I. T. 610, 720
Vose, D. A. 610, 710
Wabe, J. S. 630, 820
Wagener, G. A. 630, 310
Wagner, S. 620, 510
Walden, C. J. 610, 630
Waldman, D. E. 610, 630
Walgreen, J. A. 610, 320
Wall, G. W. 610, 630
Wall, R. A. 610, 210
Wallace, R. L. 610, 630
Wallace, W. E. 620, 920
Walton, T. F. 610, 220
Wend, M. E. 620, 110
Ware, H. 610, 620
Ware, P. M. 630, 220
Ware, R. F. 610, 630
Warren-Boulton, F. R. 610, 830
Wasmuth, E. H., Jr 610, 310
Waters, W. G. 610, 410
Watkins, T. G. 610, 630
Watson, K. 620, 100
Watson, W. F. 610, 720
Webb, L. R. 610, 020
Webb, T. C. 610, 210
Webbink, D. W. 610 630
Webbink, H. L. O. 610, 930
Weber, C. L. 600, 300
Weber, E. A. 610, 310
Weber, M. E. H. 600, 300
Weber, P. H. 610, 630
Weber, S. F. 620, 720
Weingast, B. R. 610
Weinstein, R. 610, 710
Weir, W. D. 620, 320
Weisbart, S. N. 610, 920
Weiss, F. 600, 610
Weiss, J. L. 600, 500
Weiss, L. W. 610, 630
Weissman, J. 610
Welch, P. J. 610, 020
Welles, J. G. 620, 720
Wells, J. V. 620, 610
Wend, J. S. 610, 130
Wendel, J. L. 600, 210
Wentworth, R. W. 610, 720
Werden, G. J. 600, 020
Werner, R. O. 610, 310
West, D. A. 600, 710
West, D. S. 610, 930
Weston, J. F. 610, 520
Whalen, T. J. 610, 010
Wheeler, P. K. 610, 930
White, A. P. 600, 200
White, L. J. 610, 620
White, W. J., Jr 610, 720
Whitehead, P. J. 610, 940
Whitman, M., Sr 610, 520
Whitney, S. N. 610, 010
Wick, A. E. 610, 320
Wiggins, S. N. 610, 210
Wilder, R. P. 610, 630
Wildman, S. S. 610, 620
Williams, A. P. 600, 010
Williams, E. W. 610, 040
Williams, P. L. 610, 030
Williams, R. A., Jr 610, 820
Williamson, O. E. 600, 020
Willner, L. D. 630, 110
Wilson, J. W. 600, 500
Wilson, T. A. 610, 320
Windus, M. L. 620, 610
Winicki, R. J. 610
Winn, D. N. 610, 540
Winston, C. M. 600, 630
Winter, S. I. 610, 530
Wobbekind, R. L. 610, 110
Woelfein, K. G. 610, 520
Wohar, M. 620, 610
Wolfe, R. M. 610, 630
Wong, D. P. 610, 630
Wong, W. K. 630, 210
Wood, D. F. 610, 040
Wood, D. F. 610, 510
Wood, D. O. 630, 720
Wood, E. T. 610, 000
Wood, W. C. 610, 320
Woodbury, T. S. 610, 130
Woods, D. W. 630, 720
Woodward, G. T. 640, 130
Woolf, A. 600, 040
Worthington, J. M., Jr 610, 210
Worthington, P. N. 610, 020
Wright, A. W. 610, 010
Wright, D. R. 600, 200
Wyand, M. J. 610, 050

Wyatt, G. J. 620, 210
Yale, J. P. 600, 100
Yao, D. A. 610, 620
Yarrow, G. K. 610, 020
Yordon, W. J. 610, 020
Young, D. R. 610, 930
Young, T. E. 630, 710
Zajac, E. E. 610, 020
Zak, T. A. 610, 930
Zardkoohi, A. 600, 400
Zebe, P. K. 600, 720
Zedlewski, E. W. 610, 210
Zelenitz, A. H. 610, 320
Zerbe, R. O. 610, 720
Ziberman, D. 620, 710
Zimmerman, M. B. 610, 720
Zino, M. J. 610, 020
Zohlnhofer, W. 610, 050
Zorn, T. S. 610, 520
Zycher, B. 610

700 AGRICULTURE; NATURAL RESOURCES

710 AGRICULTURE
720 NATIONAL RESOURCES
730 ECONOMIC GEOGRAPHY

Abbott, P. C. 700, 210
Abdul-Razzaq, A. H. 720
Abel, M. E. 710, 420
Abgrall, J. 720, 030
Adams, D. M. 720, 210
Adams, G. 720, 210
Adams, T. C. 720, 530
Adriasola, L. A. 720, 530
Afzal, M. 710, 120
Ahern, J. 710, 530
Airan, L. D. 720, 520
Allen, P. G. 700, 620
Allison, J. P. 720, 930
Altobello, M. A. 720, 710
Alward, G. S. 720, 110
Amos, O. M. 720, 940
Andersen, P. 720
Anderson, B. L. 710, 530
Anderson, D. L. 720, 910
Anderson, J. L. 700, 210
Anderson, L. G. 720, 020
Anderson, R. C. 720, 520
Anderson, S. J. 720
Anderson, W. C. 720, 630
Andrews, L. M. 720, 210
Angevine, G. E. 720, 130
Anschel, K. R. 710, 110
Antle, J. M. 710, 210
Arastani, R. 700, 210
Aspelin, A. L. 710, 610
Atkinson, L. J. 710, 110
Ayer, H. W. 700, 120
Baarda, J. R. 710, 610
Babb, E. M. 710, 530
Baker, C. B. 710, 310
Baker, L. B. 710
Baker, T. G. 710, 520
Balestrieri, G. 710, 530
Barbour, E. 720, 940
Barclay, R. A. 710
Barkley, P. W. 720, 930
Baroutsis, A. P. 720, 200
Barrett, L. B. 720, 610
Barry, P. J. 710, 520
Bassis, A. C. 720, 620
Basham, F. C. 720, 940
Bassi, J. 720, 940
Batista, J. C. 720, 940
Batterham, R. L. 710, 520
Baum, N. P. 720, 210
Baumgartner, D. C. 720, 530
Beach, A. E. 710, 000
Beaton, N. J. 700, 500
Beavis, B. 720, 600
Beker, V. A. 710, 020
Bell, F. W. 720, 630
Belongia, M. 710, 130
Belov, A. Y. 720, 110
Benatar, L. C. 700, 000
Bender, F. E. 710, 210
Benedetti, J. C. 720, 520
Bergen, V. 720, 020
Berman, T. F. 720, 110
Bernat, G. A., Jr 710, 940
Bernknopf, R. L. 720, 940
Bidwell, M. O. 720, 840
Biere, A. W. 710, 720
Bingham, T. H. 720, 610
Black, A. 730, 930
Blakeslee, L. 710, 210
Blyn, G. 730, 120
Boadu, F. O. 710, 210
Bockstael, N. E. 720, 020
Bodington, J. 720, 210
Boisvert, R. N. 720, 930
Bonnen, J. T. 710, 220
Bopp, A. E. 720, 210
Borcsok, A. 700, 530
Borton, R. 710, 120
Bowen, R. L. 720, 110
Bower, B. T. 720, 630
Boyne, D. H. 710, 220
Bozdogan, K. 720, 210
Braden, J. B. 720, 210
Bradley, E. B. 710, 720
Bradley, P. G. 720, 610
Bradley, R. A. 720, 030
Brady, G. L. 720, 020
Bray, J. O. 710, 010
Breimyer, H. F. 710, 610
Breslaw, J. A. 720, 210
Bresnock, A. E. 720, 900
Brinegar, G. K. 710, 440
Brinner, R. E. 720, 130
Broadman, H. G. 700, 120
Brock, T. N. 720, 520
Brodie, J. D. 720, 010
Bromley, D. W. 720, 120
Bronzi, P. 710, 120
Brookshire, D. S. 720, 210
Brower, J. C. 720, 630
Brown, D. A. J. 720, 210
Brown, E. S. 720, 930
Brown, G. 720, 020
Brown, S. P. A. 720, 320
Brunton, D. D. 720
Buchholz, W. 720, 020
Bugg, P. 720, 210
Bull, L. L. 720, 210
Buongiorno, J. 720, 210
Burrough, D. L. 720, 120
Burrows, E. M., Jr 720, 320
Burt, O. R. 700, 210
Butcher, W. R. 720, 110
Cairns, R. D. 720, 630
Callaghan, P. 720, 520
Cameron, T. A. 720, 610
Campbell, D. C. 720, 110
Campbell, K. O. 710, 720
Carlin, A. P. 720, 120
Carnes, J. N. 720, 420
Carringan, F. 720, 520
Carson, R. T., Jr 720, 200
Carson, W. D. 720, 520
Carter, H. O. 710, 210
Castle, E. N. 720, 710
Caulfield, H. P. 720, 110
Caulkins, P. P. 720, 210
Chapman, D. 720
Chappelle, D. E. 720, 940
Chase-Lansdale, W. C. 710, 600
Chattin, B. L. 710, 720
Chavas, J. 710, 210
Chavez, M. L. 720, 210
Chen, D. Y. 720, 210
Chennareddy, V. 710, 210
Chicoine, D. L. 720
Chisholm, A. H. 710, 720
Choi, J. 710, 130
Chou, J. 720, 410
Cleary, D. P. 720, 630
Clodius, R. L. 710, 610
Cohen, A. 720, 110
Cole, A. B. 720, 940
Cole, G. M. 720, 520
Cole, K. L. 720
Collings, R. A. 720, 320
Collins, D. R. 720, 940
Colosi, J. A. 720, 840
Cone, B. W. 720, 110
Conrad, J. M. 720, 020
Considine, T. J. 720, 210
Constable, G. A. (. 720, 940
Copaken, R. R. 720, 120
Copes, P. 720, 940
Cornell, N. W. 720, 610
Corsmit, C. W. 720, 940
Costello, K. W. 720, 610
Coughlin, R. L. 720, 940
Cox, P. M. J. 710, 110
Crabbe, P. J. 720, 020
Crandall, M. S. 720, 630
Craven, S. K. 720, 420
Crawford, T. L. 710, 530
Crocker, T. D. 720, 020
Cropper, M. L. 720, 850
Cross, M. L. 720, 030
Crow, R. T. 720, 940
Croyle, D. R. 720, 210
Crutchfield, S. R. 720, 020
Cummings, R. G. 720, 020
Curlee, T. R. 720, 610
Currie, B. C. 720, 120
Currie, J. W. 720, 000
Da Cruz, E. R. 710, 210
Daly, H. E. 720, 110
D'Aquino, S. A. 720, 940
Darmstadter, J. 720, 600
David, E. L. 720, 320
Davis, L. 710, 020
Davis, R. K. 720, 320
Debenedictis, M. 710, 720
Debois, J. 710, 420
De Julius, A. S. 720, 110
Delgado, C. L. 710, 110
Denuyl, R. B. 720, 400
Derr, D. A. 720, 710
Deyak, T. A. 720, 210
DeYoung, J. H., Jr 720, 210
Diemer, J. A. 720, 940
Diener, S. G. 720, 520
Dillon, J. L. 710, 210
Diltz, D. O. 710, 500
Dobson, W. D. 710, 520
Dola, M. 720, 010
Donald, D. W. 720, 210
Donnelly, W. A. 720, 210
Doran, R. K. 720, 530
Dorenfeld, D. L. 720, 130
Dorner, P. P. 710, 120
Dower, R. C. 720, 710
Downing, P. B. 720, 930
Dragun, A. K. 720, 020
Dudley, N. J. 720, 710
Duff, J. B. 710, 120
Duffield, J. W. 720, 610
Dumsday, R. G. 710, 720
Dwyer, C. J. 720, 440
Dwyer, J. F. 720, 920
Dyer, W. M. 710, 120
Ealy, C. C. 720, 610
Earley, T. C. 710, 420
Easley, J. E., Jr 720, 020
Easter, K. W. 720, 710
Eastham, G. M. 720, 030
Ebel, B. J. 720, 940
Eckerman, D. E. 710, 720
Eckert, R. D. 720, 610
Edwards, D. J. 720, 100
Egan, T. P. 720, 610
Eicher, C. K. 710, 110
Eidman, V. R. 710, 720
Eller, D. A. 710, 530
Eldon, W. D. 720, 610
Ellerman, A. D. 720, 400
Etterich, J. G. 710, 820
Emerson, P. M. 710, 010
Englin, J. E. 720, 930
Enk, G. A. 720, 610
Epp, D. J. 720, 710
Erickson, G. K. 720, 630
Erickson, L. E. 720, 320
Erwin, C. P., Jr 720, 510
Ethridge, D. E. 720, 710
Everett, M. D. 720, 900
Everson, C. K. 720, 600
Falcon, W. P. 710, 120
Falkson, L. M. 720, 020
Farmer, B. M. 700, 800
Farris, P. L. 710, 610
Faruqui, A. 720, 630
Faulkner, J. L. 720, 320
Fedeler, J. A. 710, 520
Fellows, S. M. 720, 710
Ferguson, I. S. 720, 000
Field, B. C. 720, 110
Finley, R. M. 700, 010
Firch, R. S. 710, 320
Fischer, J. D. 720, 520
Fischer, M. L. 710, 500
Fischman, L. L. 720, 010
Fisher, A. C. 720, 020
Fisher, J. L. 720, 110
Fisher, W. L. 720, 210
Fitch, J. B. 710, 620
Flaaten, O. 720, 630
Flagg, V. G. 720, 220
Flaim, S. J. 720, 210
Flannery, J. J. 720, 940
Fletcher, J. J. 720, 210
Flick, W. A. 720, 940
Flora, D. F. 720, 110
Folz, W. E. 710, 110
Forste, R. H. 720, 710
Forster, B. A. 720, 020
Forster, D. L. 710, 720
Foster, W. G. 720, 630
Fox, F. G. 720, 210
Fox, G. C. 710, 200
Fox, R. W. 710, 120
Frector, D. T. 720, 020
Franklin, D. L. 710, 820
Franklin, D. R. 720, 020
Frederick, K. D. 720, 120
Fredrickson, C. H. 720, 010
Freeman, A. M. 720, 320
French, B. C. 710, 210
Fruin, J. E. 710, 530
Fullen, R. E. 720, 940
Furtan, W. H. 710, 720
Gale, H. F. 720, 630
Gallagher, D. R. 720
Galloway, F. J. 720, 120
Gander, J. P. 720, 610
Gardner, B. D. 720, 710
Gardner, P. D. 720, 710
Garnsey, M. E. 720, 940
Garrido Egido, L. 710, 020
Geissler, P. J. 720, 210
Gemmill, G. T. 700, 400
Gerard, J. M. 720, 020
Gerrard, M. B. 720, 930
Gibbons, J. O. 720, 320
Gibson, J. A. 720, 520
Gibson, N. S. 720, 130
Gill, G. S. 720, 210
Gingerich, H. F. 710, 220
Giusti, G. P. 720, 510
Glover, T. F. 700, 800
Glyer, J. D. 720, 020
Goddard, E. W. 710, 210
Godfrey, E. B. 720, 710
Goldsmith, O. S. 700, 100
Gonzalez, G. M. 720, 320
Gonzalez, J. A. 715, 530
Gonzalez, R. J. 720, 610
Gordon, K. M. 710, 520
Gordon, R. L. 720, 600
Gould, B. W. 720, 210
Graca, L. R. 710, 620
Grebenstein, C. R. 720, 520
Greenley, D. A. 720, 010
Greer, R. C. 710, 020
Gregory, G. R. 720, 110
Gregory, W. F. 710, 110
Greulich, F. E. 720, 210
Grichar, J. S. 720, 210
Griffin, R. C. 720, 320
Griffith, M. R. 720, 130
Grove, E. W. 710, 220
Grunewald, O. C. 710
Guedry, L. J. 710, 940
Guldmann, J. M. 720, 930
Gulley, D. A. 720, A00
Hagenstein, P. R. 720, 940
Hagle, P. 730, 940
Haines, W. W. 720, 050
Hall, B. F. 710, 820
Hall, D. C. 700, 200
Hall, H. H. 710, 210
Hallberg, M. C. 710, 210
Hammig, M. D. 710, 610
Hanayama, Y. 720, 930
Hanemann, W. M. 720, 210
Hansen, C. S. 720, 940
Hansson, K. 720, 400
Hardin, L. S. 710, 440
Harkin, D. A. 720, 120
Harries, H. 720, 630
Harris, D. P. 720, 210
Harris, T. D. 700, 600
Harrison, P. 730, 940
Harvey, D. R. 710, 110
Haspel, A. E. 720, 200
Hassan, A. A. 710
Havlicek, J. 710, 210
Hayami, Y. 710, 120
Hayenga, M. L. 710, 610
Hazard, D. G. 720
Hecox, W. E. 720, 400
Hedley, D. D. 710, 210
Heifner, R. G. 710, 210
Heikkila, E. J. 720, 320
Heitmann, G. 720, 210
Helfinstine, R. D. 710, 720
Hellaten, M. 720, 210
Helmuth, J. W. 710, 530
Hemmi, K. 700, 420
Hendrix, W. E. 710, 020
Henson, W. L. 710, 210
Herr, W. M. 710, 100
Hertford, R. 710, 110
Hertzler, G. L. 700, 200
Hewlett, J. G. 720, 210
Hickenbotham, T. L. 720, 710
Hickson, A. B. 700, 940
Hildreth, R. J. 710, 720
Hillman, J. S. 710, 420
Hiremath, B. N. 710, 720
Hobson, B. W. 710, 720
Hoel, M. 720, 020
Hogarty, T. F. 720, 610
Holt, S. 720
Hooker, P. J. 720, 110
Hoover, D. M. 710, 810
Hoover, W. L. 720
Horst, R. L., Jr 720, 210
Houck, J. P. 710, 210
Houtsma, J. J. 720, 610
Howe, C. W. 720, 110
Hubbard, I. R. 720, 040
Hudder, J. J. 700, 600
Hughart, D. 720, 120
Hughes, J. P. 720, 610
Hunt, R. D. 710, 530
Huntington, H. G. 720, 210
Huppert, D. D. 720, 210
Hussen, A. M. 720
Hwang, E. 720, 930
Hyde, W. F. 720, 940
Irland, L. C. 720, 630
Irwin, G. D. 710, 520
Jakach, J. A. 720, 710
Jensen, H. H. 700, 920
Jensen, R. B. 710, 530
Jeanes, O. B. 710, 530
Jesse, E. V. 710, 210
Jessee, K. E. 710, 530
Job, C. A. 720, 110
Johnson, D. G. 710, 420
Johnson, F. R. 720, 050
Johnson, G. V. 720, 050
Johnson, J. E. 720, 710
Johnson, K. 720, 210
Johnson, M. A. 710, 610
Johnson, M. H. 720, 940
Johnson, R. E. 720
Johnson, S. E. 710, 120
Johnson, W. A. 720, 610
Johnston, J. H. 710, 320
Jones, C. V. 720, 810
Jones, D. W. 730, 040
Jones, R. C. 720, 710
Jones, W. O. 710, 920
Jordan, J. L. 700, 600
Josserand, H. P. 720, 710
Judd, M. E. 720, 520
Jungman, F. M. 710, 020
Justen, M. E. 720, 940
Kahan, A. 710, 040
Kahn, J. R. 720, 930
Kalter, R. J. 720, 320
Kane, S. M. 700
Kang, J. 710
Kanla, J. J. 720, 600
Kaplan, S. S. 720, 730
Katz, M. B. 720, 940
Kazmer, D. R. 720, 050
Keith, J. E. 720, 940
Keller, F. L. 720, 120
Kellogg, L. S. 720, 220
Kenney, J. M. 720, 320
Kiene, W. 710, 110
Kiesling, H. 710, 210
Killcer, A. Z. 720, 220
Kilmer, R. L. 710, 610
Kim, B. H. 720, 930
Kincannon, B. F. 720, 820
King, D. A. 720, 000
King, R. A. 710, 110
Kirklin, W. 730, 530
Kislev, Y. 710, 300
Klan, M. S. 720, 210
Klemperer, W. D. 720, 520
Klepper, R. 710, 110
Knapp, D. H. 720, 930
Knapp, G. P. 720
Knapp, K. C. 720, 710
Knetsch, J. L. 720, 010
Knowles, G. J. 710, 210
Koffsky, N. M. 710, 120
Kohn, R. E. 720, 010
Konkel, R. S. 720, 940
Kraft, S. E. 710, 720
Kramer, R. A. 710, 720
Kuch, P. J. 720, 850
Kuhn, B. A. 710, 530
Kumar, R. 720, 120
Kunkel, D. E. 710, 110
Ladue, E. L. 710, 520
Lamb, G. A. 720, 510
Lamm, R. M. 710, 200
Lamothe, L. R. 720, 020
Landsberg, H. H. 720, 620
Landwehr, J. B. 700, 200
Langemeier, D. L. 700, 210
Langham, M. R. 710, 210
Langton, T. G. 720
Laughlin, D. H. 710, 210
Lave, L. B. 720, 850

Learn, E. W. 710, 420
Leary, R. J. 720, 610
Lebel, P. G. 720, 110
Lee, D. R. 710, 210
Lee, K. 720, 710
Lee, K. W. 710, 530
Lee, L. 720
Leger, J. 720, 120
Lele, U. 710, 120
Leonard, K. F. 710, 020
Lerner, L. J. 720, 630
Le Roy, A. D. 720, 210
Leuthold, R. M. 710, 210
Levinson, A. L. 720, 620
Levy, J. M. 720, 630
Levy, R. A. 700, 400
Lewis, D. K. 720, 520
Lewis, G. D. 720, 530
Lewis, J. A. 700, 720
Lewis, M. 720, 020
Lewis, R. C. 720, 210
Liapis, P. S. 720, 710
Libbin, J. D. 710, 210
Libby, L. W. 720, 710
Lichtblau, J. H. 720, 630
Lichtenberg, E. R. 720, 210
Liebenthal, A. 720, 210
Lindner, R. K. 710, 620
Liu, C. L. 710, 210
Livernois, J. R. 720, 020
Lofting, E. M. 720, 940
Lonoff, M. J. 720, 630
Loomis, J. B. 720, 940
Loose, V. W. 720, 610
Lotterman, E. D. 710, 720
Lucas, E. C. 710, 120
Luzar, E. J. 720, 120
Lybecker, D. W. 710, 720
Lynne, G. D. 720, 710
Mabbe-Zeno, C. C. 720, 120
Macaulay, H. H. 710, 320
MacDonald, R. D. S. 720, 110
Maceachern, G. A. 700, 500
MacFadyen, A. J. 720, 920
MacKenzie, B. W. 720, 520
Macenick, R. M. S. 720, 110
Madden, J. P. 710, 320
Magirou, E. F. 720, 210
Major, D. C. 720, 110
Malloy, A. J. 720, 520
Manchester, A. C. 710, 630
Manderscheid, L. V. 710, 200
Mann, C. K. 710, 120
Mann, P. C. 720, 610
Manning, T. W. 710, 720
Manson, J. B. 720
Manuel, D. P. 720, 020
Marcano, J. F. 720, 210
Marhatta, H. P. 700, 530
Marin, A. M. 720, 130
Marks, R. E. 720, 020
Marshall, G. 720, 620
Marshall, H. E. 720, 020
Marshall, R. C. 720, 510
Martin, D. W. 720, 210
Martin, L. R. 700, 120
Martin, M. A. 710, 420
Martin, S. W. 720, 210
Martin, W. J. 710, 210
Marwick, D. 720, 820
Masuda, N. 720, 020
Mather, E. O. 720, 620
Mation, P. J. 710, 110
Matsuda, Y. 720, 120
Max, W. 720, 320
Mayne, Y. C. 720, 940
Mayo, D. R. 720, 610
McCalla, A. F. 710, 420
McCamley, F. 710, 210
McCann, P. G. 720, 630
McCart, H. N. 720, 940
McConnell, K. E. 710, 720
McCoy, D. R. 720, 500
McDonald, J. H. 720, 030
McDonald, V. R. 700, 400
McFarland, J. B. 720, 810
McGranahan, L. J. 700, 100
McKillop, W. 720, 210
McRae, R. N. 720, 210
Meade, N. 720, 900
Meadows, J. C. 720, 210
Meilke, K. D. 710
Memoli, N. 710, 530
Mendelsohn, R. O. 720, 900
Mendez, L. G. 710, 720
Menz, F. C. 720
Meyer, R. L. 710, 120
Meyers, W. H. 710, 210
Mian, A. Z. 720, 130
Miedema, A. K. 720, 210
Mighell, R. L. 710, 020
Miller, J. R. 720, 320
Miller, M. F. 720, 210
Miller, R. H. 720, 940
Millican, L. A. 720, 620
Million, G. S. 720, 320
Milon, J. W. 720
Miranowski, J. A. 720, 710
Misiolek, W. 720, 300
Mitchell, J. S. 720, 210
Mitnick, S. 720, 210
Miay, G. I. 710, 210
Moffat, W. R. 720, 320
Mohring, H. 720, 610
Moncur, J. E. T. 720, 210
Monteen, R. E. 720, 510
Montgomery, A. A. 720, 210
Montgomery, R. 710, 110
Montgomery, W. D. 720, 630
Moore, J. L. 720, 120
Moore, K. M. 720, 210
Morales, V. H. 720, 910
Morey, E. R. 720, 210
Morgan, P. J. 720, 600
Morgenstern, R. D. 720, 010
Moriak, T. F. 710, 210
Morris, G. E. 720, 210
Morzuch, B. J. 710, 210
Mosca, E. A. 710, 520
Moseidjord, A. 720, 610
Mueller, H. A. 720, 610
Mueller, M. J. 720, 630
Muench, J. 720, 600
Mulkey, D. 720, 940
Muller, F. G. 720, 050
Mungula, G. A. 710, 110
Munro, G. R. 720, 310
Murray, W. G. 720, 000
Murrell, W. E. 720, 400
Muse, B. 720
Mutarais, A. 710, 110
Nafziger, R. K. 720, 110
Nautiyal, J. C. 720, 210
Nelson, C. H. 720, 710
Nelson, D. K. 720, 940
Nelson, G. O. 710, 110
Nelson, R. H. 720, 930
Nelson, R. L. 720, 710
Netschert, B. C. 720, 730
New, G. F. 710, 210
Newton, M. E. 720, 940
Nilsen, S. R. 700, 800
Nobe, K. 720, 120
Noel, J. E. 710, 720
Noh, K. M. 710, 720
Nordell, L. P. 723, 613
Norgaard, R. B. 720, 110
Norton, D. T. 710, 010
Norton, G. W. 710, 110
Novakovic, A. M. 710, 610
Oelhaf, R. C. 710, 720
Ogden, D. C. 720, 410
O'Kelly, M. 730, 930
O'Laughlin, J. 720, 630
Olewiler, N. D. 720, 610
Olson, O. P. 710, 010
O'Neil, W. B. 720, 600
Orr, L. D. 720, 920
Osborn, P. N. 720, 610
Osterhoudt, F. H. 720, 710
Otto, D. M. 710, 940
Packard, R. L. 710, 720
Padungchai, S. 720, 210
Pagoulatos, A. 720, 100
Palmer-Jones, R. W. 710, 120
Palmini, D. J. 720, 300
Parker, R. B. 710, 620
Pasanen, O. N. 720, 930
Patrick, G. F. 710, 120
Patton, G. T. 720, 920
Patton, W. P. 710, 720
Paul, A. B. 710, 630
Peake, B. A. 720, 020
Pei, C. C. M. 720, 710
Penn, J. B. 710, 210
Perlack, R. D. 700, 200
Perrin, R. K. 710, 620
Peterson, D. L. 710, 800
Pherson, C. L. 710, 720
Phillips, W. E. 720, 710
Phipps, H. R. 720, 940
Phipps, T. T. 720, 210
Pickard, W. C. 700, 600
Pickel, F. H. 720, 110
Pierre-Benoist, J. 710, 100
Pillet, B. D. 710, 840
Pingry, D. E. 720, 940
Pinto, F. J. P. 720, 100
Piper, D. G. 720, 710
Pittman, R. W. 720, 610
Plotnik, A. 720, 610
Plourde, C. G. 720, 110
Poffenberger, J. R. 720, 2
Polhemus, V. D. 720, 940
Polinow, L. 720, 000
Pontecorvo, G. 720, 310
Pope, R. D. 710, 210
Porter, M. G. 720, 300
Potter, V. M. 720, 620
Prest, W. G. 720, 610
Prato, A. A. 720, 210
Prewo, W. E. 720, 400
Price, D. W. 710, 920
Provenzano, G. 720, 940
Puiliainen, K. A. 720, 110
Pulsipher, A. G. 720, 600
Pumphrey, R. G. 720, A00
Rahn, A. P. 710, 530
Raid, H. D. 710, 510
Randall, A. J. 720, 020
Rathjen, R. A. 720, 710
Raup, P. M. 700, 100
Rausser, G. C. 710, 720
Reddy, B. J. 720, 210
Reid, M. W. 720, 630
Reidinger, R. B. 710, 120
Reiss, F. P. 710, 720
Rettig, R. B. 720, 020
Reynolds, L. 720, 610
Rhee, J. J. 720, 210
Rice, W. G. 720, 130
Richards, D. P. 720, 610
Rideout, D. B. 720, 520
Rieber, M. 720, 610
Roberts, N. K. 720, 110
Robinson, R. M. 720, 520
Robison, L. J. 710, 210
Robison, M. H. 720, 940
Robson, A. J. 720, 020
Rogers, C. D. 720, 420
Rogers, R. O. 710, 510
Romain, R. F. 710, 520
Rose, A. Z. 720, 940
Rosine, J. 710, 300
Rosing, J. 720, 940
Rubin, M. 720, 050
Ruby, M. G. 720, 200
Rusin, M. 720, 610
Russell, C. S. 720, 010
Russell, R. 710, 720
Russell, T. B. 720, 120
Ruttan, V. W. 700, 110
Ryan, J. G. 710, 620
Ryan, J. W. 720, 520
Salant, S. W. 720, 020
Sandretto, C. 700, 020
Sandri, H. J. 720, 630
Sanghi, A. K. 720, 940
Santos, R. F. D. 710, 210
Sartain, J. B. 720, 610
Saylor, R. G. 710, 210
Schaefer, R. K. 720, 940
Schafer, P. H. 720, 320
Schatzer, R. J. 710, 210
Schefter, J. E. 720, 940
Schildroth, J. W. 700, 940
Schmiesing, B. H. 710, 720
Schnapp, R. M. 720, 940
Schnittker, J. A. 710, 130
Schramm, G. 720, 110
Schrimper, R. A. 710, 210
Schuler, F. M. 720, 630
Schultz, D. A. 700, 720
Schultz, T. W. 700, 800
Schurr, S. H. 720, 620
Schwart, R. B., Jr 710, 530
Scott, A. D. 720, 320
Scott, G. J. 710, 610
Scott, M. J. 720, 940
Seagraves, J. A. 700, 900
Seale, J. L., Jr 710, 210
Searls, J. P. 720
Seevers, G. L. 710, 410
Seitz, W. D. 720, 710
Selley, R. 710, 120
Seneca, J. J. 720, 320
Shaffer, J. D. 710, 610
Shane, R. L. 720, 710
Shank, M. D. 720, 530
Shechter, M. 720
Sheerin, J. C. 720, 520
Shen, R. 710, 720
Sher, G. 710, 320
Sherman, S. E. 720, 520
Shin, E. 720, 610
Shirley, F. C. 720, 010
Sigmon, B. 720
Silverman, L. P. 720, 210
Simon, M. S. 710, 200
Sims, W. A. 720, 610
Singh, A. 720, 920
Slade, M. E. 720, 210
Sloan, R. L. 710, 010
Smathers, W. M. 720, 740
Smith, D. M. 720, 110
Smith, G. A. 720, 030
Smith, H. H. 720, 710
Smith, L. J. 720, 600
Smith, N. D. J. 720, 210
Smith, P. F. 720, 530
Smith, R. J. 710, 800
Smith, S. C. 700, 900
Smith, S. N. 710, 720
Smith, T. R. 720, 520
Sokoloski, A. A. 720, 910
Solow, J. L. 720, 020
Sorensen, P. E. 720, 610
Spies, P. H. 720, 120
Spitze, R. G. F. 710, 110
Steiner, N. L. 720, 520
Stoloff, S. 720, 210
Stanley, C. E. 720, 930
Starler, N. H. 720, 710
Steele, J. T. 710, 510
Stefanou, S. E. 700, 210
Stevens, B. K. 720, 210
Stevens, T. H. 720, 320
Stevenson, W. W. 720, 630
St George, G. E. 710, 210
Stoll, J. R. 720, 320
Stoltenberg, C. H. 720, 710
Storer, J. A. 720, 110
Streifel, S. 720, 210
Stroh, C. M. 720
Stroup, R. L. 720, 820
Suchy, K. W. 720, 010
Sukhatme, V. A. 710, 110
Sullivan, E. T. 720, 000
Sullivan, J. A. 720, 630
Sullivan, W. B. 720, 600
Sumner, D. A. 710, 800
Sutinen, J. G. 720, 020
Sutton, R. E. 710, 210
Szabo-Pelsoczi, M. 720, 400
Szopo, I. E. 720, 500
Talheim, D. R. 720, 210
Tarasov-Reed, H. 720, 920
Tauer, L. W. 710, 310
Taylor, G. C. 710, 720
Taylor, R. C. 710, 440
Taylor, T. G. 710, 210
Tejada, M. L. 720, 620
Telson, M. L. 720, 610
Tenenbaum, E. 720, 220
Thirtle, C. G. 710, 320
Thomas, W. C. 710, 720
Thompson, W. N. 710, 440
Tietenberg, T. H. 720, 930
Tilley, D. S. 710, 220
Tilton, J. E. 720, 620
Timmer, P. 710, 110
Timmons, J. F. 720, 110
Tober, J. A. 720, 000
Tollens, E. F. 710, 110
Toman, M. A. 720, 210
Tomek, W. G. 710, 210
Tona, C. 710, 110
Topping, C. P. 720, 630
Touchstone, S. K. 720, 850
Toussaint, W. D. 710, 010
Tregarthen, T. D. 720, 900
Trostle, R. G. 710, 440
Tryon, J. L. 720, 110
Tucker, D. 710, 530
Turner, A. K. 720, 930
Turner, J. D. 710, 720
Tussing, A. R. 720, 110
Tweeten, L. G. 710, 110
Tybout, R. A. 720, 630
Tyner, W. E. 720, 110
Tyrchniewicz, E. W. 710
Ulph, A. M. 720, 020
Unruh, M. N. 720
Updew, N. J. 710, 010
Urquhart, N. R. 710, 720
Vandeverg, E. 700, 930
Van Kooten, G. C. 720
Van Tassel, A. J. 720, 620
Vaux, H. J. 720, 320
Veeman, T. S. 700, 120
Veramallay, A. I. 720, 110
Verleger, P. K. 720, 210
Vincent, W. H. 710, 120
Visgilio, G. R. 720, 020
Vlachou, A. S. 720, 120
Voertman, R. F. 700, 000
Vogely, W. A. 720, 210
Wade, W. W. 720, 710
Wadyka, W. S. 720, 610
Wahl, R. W. 720, 020
Walker, J. L. 720, 520
Wall, H. 720, 630
Walsh, R. G. 720, 610
Walter, B. J. 710, 010
Walter, G. R. 720, 930
Walton, A. L. 720, 620
Wan, R. S. 720, 020
Wang, K. 720, 210
Ward, F. A. 720, 020
Warner, M. L. 710, 020
Waters, R. C. 720, 620
Watson, W. D. 720, 630
Waugh, G. H. 720
Waxmonsky, R. W. 730, 940
Webb, A. J. 710, 410
Weber, J. C. 720, 210
Webre, P. C. 720, 600
Weeks, E. E. 710, 010
Weimer, D. L. 720, 610
Weiss, A. B. 720, 600
Wells, F. J. 720, 610
Wells, G. R. 720, 700
Welsch, D. E. 710, 120
West, L. A. 710, 210
Wetzel, J. N. 720, 930
Whelan, W. P. 710, 120
Whitaker, M. D. 710, 110
Whitaker, R. L. 720, 610
White, F. L., Jr 720, 520
Whitworth, R. L. 720, 320
Wile, J. H. 720, 930
Willett, D. A. 720
Willett, K. D. 720, 320
Willman, E. A. 720, 940
Wilson, J. D. 720, 210
Wilson, L. M. 710, 510
Wilson, P. N. 710, 440
Winkelmann, D. 710, 110
Wipf, L. J. 710, 400
Witt, L. W. 710, 420
Wohlgenant, M. K. 710, 630
Wolf, M. M. 720, 940
Wollman, N. 720, 940
Wolman, A. 720, 320
Wood, G. H. 720, 000
Workman, W. G. 720, 020
Wu, C. K. H. 720, 940
Wunderlich, G. L. 720, 110
Yance, J. V. 720, 610
Yeboah, A. O. 710, 110
Yepez, L. F. 710, 110
Yeung, P. 710, 100
Yokell, M. D. 720, 600
Yoshida, J. 710, 530
Young, R. A. 720, 710
Zahn, M. D. 710, 100
Zeimetz, K. A. 720, 930
Ziegler, L. F. 720, 420

800 MANPOWER; LABOR; POPULATION

810 MANPOWER TRAINING AND ALLOCATION, LABOR FORCE AND SUPPLY
820 LABOR MARKETS, PUBLIC POLICY
830 TRADE UNIONS, COLLECTIVE BARGAINING, LABOR-MANAGEMENT RELATIONS
840 DEMOGRAPHIC ECONOMICS

Abraham, J. D. 830, 910
Abrahamson, A. 820, 830
Adamache, K. P. 820, 910
Adams, A. V. 810, 820
Adams, J. L. 820, 910
Adams, J. P., Jr 820, 130
Adams, L. P. 820, 830
Adkins, R. L. 800, 050
Adnett, N. J. 820, 810
Alexander, K. O. 830, 820
Allen, J. M. 840, 820
Allen, S. G. 820, 830
Allison, E. 820, 810
Alper, N. O. 810, 820
Alpert, W. T. 810, 110
Alsalam, N. 820, 850
Althaus, P. G. 840, 110
Anderson, B. E. 820, 100
Anderson, J. F. 800, 420
Anderson, J. M. 840, 400
Anderson, K. H. 840, 810
Andress, R. A. 800, 530
Andrews, E. S. 820, 910
Andrews, W. H. 810, 630
Antos, J. R. 820, 200
Applebaum, L. 830, 820
Arnold, T. R. 830, 610
Ascah, L. G. 830, 020
Ashenfelter, O. C. 800, 200
Asher, M. A. 820, 130
Atherton, W. N. 820, 830
Atrostic, B. K. 800, 200
Augustyniak, C. M. 840, 320
Austermiller, C. J. 830, 820
Austin, P. E. 810, 610
Azevedo, R. E. 820, 830
Babu, D. S. 840, 220
Bachman, W. A. 830, 310
Bailer, L. H. 830, 820
Bailey, D. 800, 020
Bailey, W. R. 820, 220
Bain, T. 800, 000
Baker, J. D. 810, 850
Baker, T. D. 850, 910
Baldwin, S. E. 810, 820
Ballot, M. H. 830, 510
Bander, N. H. 810, 110
Banerjee, B. 800, 110
Barichello, R. R. 850, 710
Barkey, P. M. 820, 210
Barkin, S. 810, 830
Barkume, A. J. 820, 930
Barlow, A. C. 810, 850
Barlow, R. F. 830, 510
Barnes, C. H. 800, 300
Barnes, R. O. 840, 920
Barnes, W. F. 820, 910
Barnow, B. S. 810, 320
Bartel, A. 820, 840
Barth, M. C. 820, 610
Barton, M. F. 810, 320
Bartsch, W. H. 810, 120
Bass, H. L. 830
Bassi, L. J. 810, 210
Battaile, R. C. 810, 850
Bauder, R. S. 830, 000
Bauer, A. P. 820, 030
Bazzoli, G. J. 810, 020
Beadles, N. A. 830, 010
Bebensee, M. A. 810, 060
Beck, E. M. 820, 610
Becker, W. E. 850, 210
Beckerman, W. 820, 320
Behman, S. 820, 830
Beland, R. 810, 820
Bell, D. 810, 820
Bell, E. B. 850, 000
Bell, L. 800, 930
Bellante, D. 820, 810
Beller, A. H. 820, 850
Bellinger, W. K. 830, 930
Benham, H. C. 820, 210
Benjamin, A. 840, 940
Benjamin, J. 800, 220
Benjamin, V. C. 820, 930
Bennett, C. A. 820, 060
Ben-Porath, Y. 800
Benson, C. S. 850, 820
Benus, J. M. 850, 810
Berger, M. C. 820, 850
Bergmann, B. R. 820, 130
Berliner, H. A. 850, 300
Bernstein, R. 800
Berry, D. W. 810, 120
Bers, M. K. 830, 820
Betcke, E. R. 820, 320
Betsey, C. L. 800, 930
Better, M. B. 830, 810
Bianchi, C. 840, 540
Bible, P. J. 810, 820
Bielby, W. T. 820, 210
Bieley, P. M. 840, 310
Bilsborrow, R. E. 840, 110
Bishop, J. H. 850, 810
Black, M. 850, 910
Blackhurst, W. G. 840
Blair, L. M. 800, 600
Blakemore, A. E. 820, 850
Blau, F. D. 820, 810
Blaug, M. 850, 030
Block, K. W. 830, 810
Block, M. K. 800, 600
Block, R. N. 830, 820
Bluestone, B. 820, 910
Boal, W. M. 800
Boden, L. I. 820, 910
Bodenhoefer, H. J. 810, 820
Bognanno, M. F. 810, 830
Bolle, M. D. 810, 820
Bollman, R. D. 820, 710
Bonifield, W. C. 810, 830
Booth, J. H. 810, 820
Boothby, D. W. 800, 300
Borjas, G. J. 800, 210
Borus, M. E. 810, 820
Bossen, M. 820, 930
Boulet, J. 820, 220
Boutler, B. L. 840, 120
Bourdon, C. C. 830, 120
Bowen, I. 840, 110
Bower, L. G. 800, 600
Bowlby, R. L. 800, 910
Bowman, M. J. 850, 120
Bowman, W. R. 800, 130
Boyle, C. E. 830, 810
Brainerd, C. P. 800, 920
Brand, M. 830, 010
Braun, S. 820, 320
Brechling, F. P. 810, 820
Breneman, D. W. 820, 810
Brennan, G. A. 830, 440
Briggs, V. M. 810, 810
Brinkmann, G. 800, 100
Brosnan, P. A. 800, 050
Brown, C. 800, 910
Brown, C. C. 820, 810
Brown, D. G. 820, 510
Brown, E. C. 830, 820
Brown, J. N. 820, 210
Brown, M. L. 820, 830
Brown, R. C. 810, 010
Brown, R. E. 830, 060
Bruce, C. J. 820, 830
Buckley, L. F. 820, 040
Burke, G. 810, 820
Burkhauser, R. V. 800, 900
Burnim, M. L. 810, 320
Burtless, G. T. 820, 910
Burton, J. F., Jr 820, 830
Burtt, E. J. 820, 030
Bussey, E. M. 800, 000
Butler, A. D. 820, 810
Buttari, J. J. 800, 120
Butter, I. H. 810, 850
Cain, G. G. 810, 820
Cain, L. F. 830, 820
Caldwell, S. B. 840, 210
Cangialosi, J. S. 810, 930
Capen, M. M. 830, 210
Carliner, G. 810, 820
Carlson, N. W. 830, 040
Carnes, C. J. 800, 310
Carow, R. J. 810, 820
Carr, T. J. 820, 210
Carvajal, M. J. 850, 210
Cassidy, W. J. 830, 810
Catanese, A. V. 800, 910
Cave, G. E. 810, 210
Cavin, E. S. 810, 830
Cazenave, P. 850, 850
Chaikind, S. B. 800, 000
Champlin, F. C. 830, 510
Chandrasekar, K. 820, 220
Chao, D. N. W. 840, 020
Chellus, J. R. 800, 600
Chernick, J. 800, 000
Cheskin, I. W. 830, 510
Cheung, L. 810, 630
Chinloy, P. 800, 000
Chiswick, B. R. 800, 200
Choudhury, M. A. 800, 200
Christainsen, G. B. 820, 320
Christensen, S. 800, 910
Christopher, R. B. 810, 210
Chudzinski, J. 800, 300
Clague, E. 810, 620
Clark, G. L. 820, 730
Clark, H. F. 810, 110
Clark, R. L. 810, 820
Clatanoff, W. B., Jr 810, 220
Cline, H. M. 800, 210
Cochrane, S. H. 840, 110
Coffey, R. M. 800, 900
Coffin, D. A. 810, 930
Cohen, S. 820, 830
Combs, J. P. 800, 940
Conger, D. J. 840, 050
Connolly, M. D. 830, 820
Contini, B. 800, 010
Cook, W. G. 830, 820
Cooper, D. E. 830, 810
Cooper, M. D. 810, 210
Cooper, R. V. L. 820, 210
Coppock, D. S. 810, 820
Corkum, K. H. 810, 310
Corman, H. 810, 320
Correa Do Lago, L. A. 800, 040
Corson, W. S. 810, 910
Costa Silva, M. I. 810, 820
Cottingham, P. H. 800, 900
Courchane, M. 820, 610
Craig, E. D. 850, 320
Crist, W. D. 820, 830
Crois, J. H. 830, 510
Cross, C. S. 800, 900
Crowell, E. 800, 910
Crowley, M. F. 810, 000
Cruze, A. M. 810, 910
Cuca, R. 840, 440
Culler, S. D. 810, 210
Cullinan, P. R. 810, 820
Cunningham, J. S. 850, 820
Curington, W. P. 820, 910
Cutler, H. A. 850, 010
Cymrot, D. J. 800, 610
Cypin, J. G. 800, 050
Dabney, H. L. 830, 810
Dale, L. A. 830, 510
Datcher, L. P. 820, 810
Daubigney, J. P. 820, 120
Davidson, G. B. 810, AOO
Davies, J. B. 800, 320
Davis, D. L. 820, 300
Davis, J. C. 810, 850
Dean, E. R. 820, 110
Deane, R. G. 830, 810
Debeer, J. 840, 210
de Duarte Matias, M. H. 850, 220
Defreitas, G. E. 820, 210
Deitsch, C. R. 830, 810
Dell Aringa, C. 820, 130
Demeny, P. 840, 120
Denend, L. G. 810, 210
Denison, E. L. 810, 000
Densiow, D. 820, 110
Depperschmidt, T. O. 830, 610
Detray, D. N. 840, 120
Devaney, B. 840, 810
Devine, E. J. 810, 820
Devino, W. S. 830
Devol, K. R. 820, 940
Dewald, S. C. 800, 600
Dickens, W. T. 820, 830
Dickinson, K. 810, 910
Dieber, W. A. 840, 930
Dillingham, A. E. 820, 810
Di Pietro, A. E. 800, 900
Director, S. M. 820, 810
Dobbelaere, A. G. 820, 830
Dodge, D. A. 800, 320
Doeringer, P. B. 820, 810
Doescher, T. A. 810, 840
Doinick, D. 830, 820
Donn, C. B. 830, 820
Dooley, M. D. 820, 840
Dost, J. E. 810, 820
Doty, M. G. 810, 220
Douty, H. M. 820, 830
Drake, C. G. 810, 900
Dresch, S. P. 840, 210
Drossopoulos, T. 810, 520
Drysdale, R. S. 800
Dudra, M. 830, 820
Duggan, J. E. 810, 210
Duncan, G. J. 810, 920
Dunlop, J. T. 830, 820
Dworkin, J. B. 830, 810
Dyckman, Z. 820, 850
Eastman, B. D. 810, 210
Eaton, P. J. 850, 810
Edgar, A. L. 810, 840
Edwards, L. N. 800, 200
Ehrenberg, R. G. 800, 210
Ehrenhalt, S. M. 800, 220
Ehrlich, I. 800, 600
Elibott, R. 830, 410
Eisenberg, W. L. 830, 820
Ekahitanonda, S. 810, 510
Elbaum, B. 830, 040
El-Fayoumy, S. G. A. 840, 540
Elliott, R. D. 820, 830
Elliott, R. F. 800, 130
Ellwood, D. T. 800, 900
Emerson, R. D. 820, 210
Endresen, M. C. 830
Englander, F. J. 800, 910
Englander, V. M. 800, 910
Enholm, G. 800, 930
Erk, N. 810, 820
Ernst, M. 820, 510
Espenshade, T. J. 840, 200
Evans, R. 810, 820
Evans, V. J. 840, 810
Evenson, J. A. 850, 210
Falaris, E. M. 810, 820
Farber, H. S. 820, 830
Faurot, D. J. 820, 210
Fearn, R. M. 810, 820
Fechter, A. E. 800, 910
Feichtner, R. 850, 620
Felder, H. E. 800, 910
Fernandez, R. L. 820, 130
Fichtenbaum, R. H. 820, 020
Fields, G. S. 820, 120
Filer, R. K. 800, 900
Fine, L. 810, 820
Finegan, T. A. 810, 820
Finifter, D. H. 820, 810
Fischer, F. J. 820, 810
Fischer, L. H. 830, 820
Fischman, E. R. 810, 840
Fisher, M. R. 850, 020
Fitzgerald, J. G. 850, 210
Fitzpatrick, B. 810, 850
Flanagan, R. J. 820, 810
Fleisher, B. M. 800, 840
Fogel, W. A. 800, 900
Folbre, N. 840, 120
Forkosch, M. D. 830
Fotis, S. W. 810, 010
Fraker, T. M. 820, 840
Frank, J. L. 820, 720
Fraundorf, M. N. 800
Freedman, A. 830, 820
Freedman, D. S. 840, 920
Freedman, M. 820, 810
Freiden, A. 810, 910
Frejka, T. 840, 110
Froomkin, J. 850, 620
Fuchs, V. R. 800, 600
Fulton, J. F. 830, 010
Gallagher, J. F. 830, 220
Ganeshan, J. J. 810, 210
Gang, I. N. 800, 120
Garnel, D. 830, 820
Garonna, P. 820, 840
Garvey, N. A. 810, 850
Gates, J. H. 850, 210
Gavin, M. H. 830, 820
Gayer, P. D. 820, 810
Gendel, E. B. 820, 830
Gerhart, P. F. 830, 800
Geruson, R. T. 840, 930
Gery, F. W. 800, 130
Geske, T. G. 850, 910
Gibbons, A. D. 850, 320
Gifford, A. 820, 830
Gilbert, K. S. 800, 320
Gill, F. 830
Gilroy, C. L. 810, 820
Gingrich, P. A. 840, 820
Ginsburg, H. 800, 900
Ginzberg, E. 820, 930
Gitlow, A. L. 820, 930
Gitter, R. J. 820, 220
Gleason, S. E. 800, 610
Glover, R. W. 800, 910
Goddard, J. B. 800, 520
Goetz, S. A. 800, 100
Gohmann, S. F. 810, 820
Goldberg, F. 810, 820
Goldberg, J. P. 830, 620
Goldberg, M. S. 800, 210
Goldfarb, M. G. 810, 850
Goldfarb, R. S. 820, 320
Goldman, B. S. 810, 910
Goldman, F. 840, 930
Goldstein, H. 800, 220
Goodfarb, L. E. 820, 840
Gordon, D. M. 820, 930
Gordon, N. M. 820, 210
Gottschalk, P. 820, 910
Gramm, W. L. 810, 020
Granovetter, M. 820, A00
Gray, W. B. 820, 220
Greckel, F. R. 810, 020
Greenberg, D. H. 810, 910
Greenberg, J. 810, 820
Greenhalgh, C. A. 820, 120
Gregory, P. 820, 120
Gregory, R. G. 820, 420
Greig, R. A. 820, 610
Grenier, G. 840, 910
Griffiths, L. C. 810, 320
Grimm, K. D. 810, 820
Groesbeck, J. D. 830, 910
Grossbard, A. 840, 820
Grosse, S. O. 840, 120
Grossman, J. B. 800
Gruenberg, G. W. 830, 820
Grunfel, J. 810, 000
Gunderson, M. K. 800, 910
Gustafson, T. A. 800, 610
Gustman, A. L. 800, 910
Guthrie, H. W. 800, 900
Gwartney, J. D. 850, 830
Haber, S. E. 810, 820
Haener, A. 800, 900
Hagemann, R. P. 840, 220
Haines, J. S. 850, 820
Hall, G. A. 830, 810
Ham, J. C. 800
Hamer, T. P. 810, 830
Hamermesh, D. S. 820, 910
Hancock, K. 820, 910
Handsaker, M. 830, 000
Handsaker, M. L. 830, 220
Hankin, R. A. 810, 910
Hansen, G. B. 810, 830
Hansen, J. M. 810, 820
Hansen, R. B. 840, 610
Hansen, W. L. 850, 810
Hanushek, E. A. 820, 930
Happel, S. K. 840, 100
Hardin, E. 810, 820
Harkavy, O. 840, 310
Harrison, D. S. 820, 130
Harter, L. G. 830, 820
Hartline, N. L. 800, 040
Hartman, H. G. 830, 030
Hartman, P. T. 830, 820
Hartman, R. W. 800, 320
Hartog, J. 850, 320
Hashimoto, M. 820, 840
Haskell, M. A. 800, 320
Hawley, C. B. 820, 800
Helan, B. C. 820, 110
Helkensten, L. J. 820, 420
Hellmann, R. L. 800, 600
Helsler, J. B. 800, 600
Helberger, C. 800, 910
Held, P. J. 820, 210
Helfgott, R. B. 810, 830
Heller, S. C. 810, 210
Helmreich, T. C. 830, 110
Henderson, J. P. 800, 030
Hendricks, W. E. 830, 610
Heneman, H. G., Jr 800
Henle, P. 800, 220
Henry, R. M. 820, 850

Hens, V. G. 820, 210
Herlihy, H. M. 820, 830
Herman, E. E. 830, 810
Hermstadt, I. L. 810, 820
Hervitz, H. M. 840, 940
Herzog, J. R. 840, 120
Hess, P. N. 840, 120
Hicks, W. W. 840, 120
Hiestand, D. L. 800, 930
Higgins, N. 800, 040
Hight, J. E. 820, 810
Hill, M. A. 810, 840
Hill, M. S. 810, 840
Hill, S. E. 800, 810
Hilmer, S. 800
Hirsch, B. T. 820, 830
Hislop, R. I. 830, 310
Hoffman, E. P. 820, 210
Hoffman, S. D. 820, 010
Hoffmann, E. 810, 220
Hogan, P. F. 820, 210
Hogan, T. D. 840, 900
Hogan, W. 840, 200
Hokenson, R. F. 840, 130
Holden, K. C. 820, 840
Holen, A. 820, 810
Holland, J. 810, 610
Hollander, E. D. 820, 120
Hollister, R. G. 800, 210
Holmes, A. B. 850, 930
Holmes, D. N. 800, 110
Holt, C. C. 820, 320
Holtmann, A. G. 850, 930
Holzer, H. J. 820, 810
Hon, R. C. 830, 520
Hooks, J. M. 820, 220
Horowitz, A. M. 800, 900
Horowitz, M. A. 810, 830
Horrigan, M. W. 820, 020
Hosek, S. 810, 920
Hotz, V. J. 810, 210
Houska, M. D. 800, 940
Hsu, S. 800, 940
Hudgins, L. L. 840, 100
Hudson, C. R. 830, 050
Hudson-Wilson, S. 820, 940
Huff, M. 820, 830
Huffman, W. E. 850, 110
Hunt, A. 820, 810
Hunt, J. C. 810, 850
Hunter, L. C. 800, 600
Hurd, S. J. 850, A00
Hurwitz, J. C. 830, 910
Hussain, M. 820, 120
Hutchens, R. M. 820, 910
Hutner, F. C. 810, 610
Hyclak, T. J. 820, 830
Iacobelli, J. L. 800, 500
Iden, G. R. 820, 320
Ihnen, L. A. 850, 710
Imah, E. B. 810, 820
Ingber, M. L. 800, 900
Ito, S. 800, 850
Jackson, G. A. 850, 220
Jackson, L. W. 830, 320
Jackson, M. 820, 810
Jacoby, S. M. 830, 040
Jakubson, G. H. 800, 210
James, E. 800, 900
Jencks, C. 820
Jensen, E. 840, 210
Jeszeck, C. 830, 930
Jochnowitz, R. S. 820, 840
Johnson, D. B. 830, 820
Johnson, J. L. 820, 810
Johnson, K. 800, 920
Johnson, T. R. 810, 910
Johnson, W. G. 810, 910
Johnson, W. R. 820, 910
Johnston, J. W. 830, 510
Jones, B. A. P. 800, 820
Jones, C. D. 820, 320
Jones, D. C. 800, 050
Jones, E. 830, 030
Jones, E. B. 810, 850
Jones, L. B. 800, 040
Jonish, J. E. 820, 810
Joyce, J. M. 800, 610
Judge, J. J. 830, 020
Juris, H. A. 830, 810
Kahley, W. J. 800, 400
Kahn, F. A. 810, 820
Kahn, L. M. 830, 820
Kahn, M. L. 830, 820
Kahn, P. L. 820, 320
Kahn, S. 820, 830
Kahne, H. 810, 820
Kaiser, C. P. 820, 830
Karger, J. 810, 820
Kasper, H. 800, 900
Katz, A. M. 820, 810
Katz, D. A. 820, 210
Katz, H. C. 830, 820
Katzman, M. T. 840, 720
Kaucki, E. F. 810, 820
Kaufman, R. T. 820, 310
Kaun, D. E. 820, 850
Kay, I. T. 820, 810
Keeley, M. C. 840, 020
Kenny, L. W. 800, 320
Kerachsky, S. H. 810, 850
Kerr, C. 830, 820
Kessel, H. 800, 900
Ketchum, E. J. D. 820, 110
Khawaja, D. A. 850, 030
Kidder, A. E. 810, 210
Kidder, D. E. 810, 910
Kiker, B. F. 850, 020
Killingsworth, M. R. 800, 000
King, C. B. 820
King, J. 810, 510
King, R. H. 850, 810
King, T. 840, 100
King, W. D. 820, 320
Kingston, J. L. 810, 820
Klay, R. 820, 110
Klees, S. J. 850, 110
Klein, B. W. 810, 610
Klein, D. P. 800, 220
Klein, K. K. 810
Klein, R. J. 810, 440
Kleiner, M. M. 820, 830
Kleinsorge, P. L. 820, 830
Knapp, C. B. 800, 300
Knickman, J. R. 810, 910
Kniesner, T. J. 810, 820
Knight, R. E. L. 830, 610
Koeller, C. T. 800, 210
Koeune, J. 800, 300
Kohen, A. I. 820, 060
Kool, K. L. 800, 100
Kopecky, H. P. 820, 510
Kornreich, S. 820, 810
Kostner, E. 810, 110
Kovacs, A. E. 830, 030
Kraft, A. 800, 210
Kramer, L. 830, 520
Kreider, L. E. 800, 400
Krepe, J. M. 810, 820
Kroopnick, E. 820, 310
Kuhl, W. O. 830, 820
Kuhmerker, P. G. 830, 220
Kuhn, J. W. 830, 810
Kuhn, P. J. 800, 920
Kuljurgis, B. G. 800, 900
Kunze, K. 840, 020
Lacey, T. R. 800, 100
Landes, E. M. 820, 610
Landolt, R. G. 830, 610
Lang, K. 820, 850
Langley, P. C. 810, 820
Lanier, C. N. 820
Larson, D. A. 800, 930
Latanich, G. A. 820, 930
Lave, J. R. 800, 900
Layard, R. 820, 320
Lazear, E. 800, 000
Lecht, L. A. 810, 110
Ledent, J. P. 840, 940
Lee, D. L. P. 820, 600
Lee, J. S. 810, 820
Lee, R. D. 840, 210
Lee, W. J. 800, 000
Leftwich, H. M. 830, 810
Lehrer, E. L. 800, 100
Leibbrandt, G. J. 820, 320
Leibowitz, A. 810, 840
Leigh, D. E. 820, 830
Leigh, J. P. 820, 210
Leighton, L. S. 810, 820
Leiserson, M. W. 800, 120
Lemelin, C. 850, 910
Lenihan, P. M. 810, 830
Leonard, J. S. 820, 320
Leonesio, M. V. 810, 910
Leppel, K. 810, 840
Lerman, R. I. 820, 910
Lerner, A. 820, 810
Lester, R. A. 820, 830
Levin, H. M. 810, 820
Levine, D. S. 800, 900
Levine, S. B. 830, 820
Levine, V. 810, 820
Levinson, D. 830, 320
Levy, R. A. 820, 620
Lewin, R. R. 820, 630
Lewis, D. R. 850, 060
Lewis, H. G. 810, 840
Leyba, E. I. 800, A00
Li, E. H. 850, 820
Lieberman, M. O. 820, 320
Liggett, M. H. 800, 610
Lim, J. D. 820, 210
Lingle, R. C. 820, 020
Link, C. R. 810, 910
Lipsky, D. B. 830, 820
Liska, T. L. 810
List, C. 850, 110
Little, R. D. 810, 620
Littman, D. A. 820, 320
Litzinger, P. J. 840, 040
Liu, P. W. 850, 020
Lloyd, C. B. 840, 820
Loewy, S. B. 810, 840
Logan, S. P. 840, 220
Long, A. L. 800, 320
Long, J. E. 820, 320
Love, T. M. 830, 010
Low, S. A. 850, 810
Lubitz, I. S. 820, 210
Lucas, R. E. B. 800, 400
Ludolf, G. W. 830, 820
Luery, D. A. 810, 930
Lukaczer, M. 810, 910
Lumsden, K. G. 850, 830
Lundberg, S. J. 800
Lurie, M. 810, 820
Luu, M. 840, 210
Lyon, R. 810, 820
MacDonald, G. M. T. 800, 020
Macedo, R. B. M. 820, 210
MacFarlan, A. M. 850, 020
MacUrdy, T. E. 810, 210
Madden, J. F. 800, 940
Maehara, Y. 830, 310
Malmon, R. R. 840, 220
Main, B. G. M. 820, 810
Maira, L. S. 810, 210
Makhija, I. 840, 020
Maki, D. 810, 820
Malakoff, A. L. 820
Mallan, L. B. 810, 910
Maller, C. D. 810, 210
Malm, F. T. 800, 510
Malmquist, D. H. 820, 400
Maloy, T. M. 830, 130
Malveaux, J. M. 800, 930
Mamer, J. W. 820, 850
Mandelstamm, A. B. 800, 300
Mann, B. S. 820, 210
Marcus, A. J. 820, 210
Marcus, R. D. 820, 610
Marder, W. D. 850, 910
Mardfin, D. W. 840, 100
Marelli, B. 820, 620
Marion, G. 800, 020
Marks, L. D. 820, 910
Marston, S. T. 820, 610
Martin, D. L. 820, 610
Martin, P. L. 820, 830
Martinello, F. 830, 720
Mason, A. W. 840, 210
Mason, J. D. 820, 910
Mason, P. F. 820, 940
Masters, S. H. 820, 810
Mathis, P. C. 800, 020
Matta, B. N. 810, 220
Mattila, J. P. 820, 810
Maurizi, A. R. 820, 850
Mauro, M. J. 800, 310
Maxfield, M. 820, 910
Maxwell, N. L. 820, 840
Meyer, E. S. 810, 820
Mayer, P. C. 810, 020
Maynard, R. A. 810, 910
McBrearty, J. C. 830, 040
McCaffree, K. M. 800, 910
McCausland, A. S. 820, 830
McClung, R. L. 850, 820
McConnell, C. R. 820, 010
McCrea, J. M. 800, 020
McDermed, E. A. 850, 720
McDevitt, T. M. 840, 120
McDowell, J. M. 850, 610
McElroy, M. B. 810, 210
McHugh, T. F. 840, 850
McIntire, J. L. 800, 130
McIntyre, M. C. 850, 320
McKechnie, G. H. 810, 830
McKee, W. L. 810, 940
McLain, J. M. 830, 920
McLauchlan, J. M. 810, 820
McLaughlin, C. G. 800, 910
McLaughlin, F. M. 820, 830
McLean, R. A. 800, 020
McLewin, P. J. 820, 040
McMahon, P. J. 820, 020
McManus, L. A. 820, 220
McMillan, R. E. 830, 510
McNabb, R. 800
McNally, K. V. 850, 810
McNaught, W. 820, 930
McNicoll, G. 840, 110
McPherson, W. H. 830, 000
McReynolds, A. D. 800, 400
Meade, B. M. 820, 210
Meesell, R. F. 810, 850
Mellow, W. S. 800, 200
Meltz, N. M. 820, 810
Menefee, J. A. 810, 900
Menefee, R. G. 830, 310
Menke, T. J. 810, 040
Merrick, T. W. 840, 110
Mertaugh, M. 840, 110
Mertens, W. 840, 120
Mestre, E. R. 800, 110
Mestrovich, M. J. 840, 610
Meyer, P. J. 800, 600
Meyer, R. H. 800, 210
Mezger, M. 800, 410
Michael, R. T. 840, 920
Mickens, A. D. 810, 820
Mickey, J. L. 840, 220
Mikami, F. 820, 020
Miller, F. H., Jr 810, 210
Miller, L. S. 810, 910
Miller, S. M. 810, 110
Mills, D. Q. 830, 630
Milne, N. D. 810, 940
Mincer, J. 800, 010
Mirer, T. W. 800, 910
Misra, S. 820, 940
Mitchell, D. J. B. 830, 820
Mitchell, O. S. 800, 910
Mixon, J. W., Jr 820, 720
Mogull, R. G. 800, 200
Monk, D. H. 850, 940
Montador, R. B. 820, 300
Montalvan, G. P. 820, 120
Moock, P. R. 850, 110
Mooney, J. 820
Moore, G. A. 800, 610
Moran, R. J. 820, 850
Morlasini, B. 810, 020
Morsland, R. S. 840, 610
Morswedge, H. 800, 300
Morgan, C. A. 840, 940
Morsch, W. C. 810, 110
Morton, C. W. 830, 510
Morton, H. C. 820, 720
Moser, J. W. 820, 830
Moss, M. 840, 220
Moss, P. I. 820
Moss, R. L. 810, 320
Moss, R. W. 800, 900
Moulton, B. R. 800, 610
Mounts, W. S. 820, 720
Mowen, M. M. 810, 540
Mueller, E. 840, 120
Mulart, J. C. 830, 060
Muller, C. F. 810, 850
Muller, L. S. 810, 210
Murnane, R. J. 810, 910
Murphy, K. J. 820, 210
Murray, M. 830, 030
Musgrave, F. W. 850, 820
Myers, S. C. 800, 210
Nadiemen, L. 840, 910
Neumann, G. R. 800, 210
Newman, D. K. 820, 920
Newman, R. J. 820, 940
Niemi, B. 810, 850
Nisenoff, L. 800, 040
Nosh, H. J. 850, 050
Nolan, S. D. 820, 810
Norgren, P. H. 820, 930
Norris, J. M. 820, 810
Northrup, H. R. 830, 820
Novos, I. E. 820, 420
Oaxaca, R. L. 800, 210
Ockert, R. A. 830, 810
O'Connell, J. F. 820, 210
O'Donnell, L. A. 830, 010
Oettinger, M. P. 830, 820
Ogawa, N. 800, 830
O'Hara, D. J. 800, 200
Ohtsu, M. 820, 830
O'Leary, C. J. 800, 210
Olson, L. 850, 840
Olszewski, D. E. 800, 930
Omarzai, M. A. K. 810, 400
O'Neill, D. M. 800, 900
O'Neill, J. E. 800, 910
Oppenheimer, M. M. 800
Orszem, P. 850, 600
Orcutt, D. R. 830, 610
Orr, J. A. 800, 940
Orton, E. S. 820, 040
Osberg, L. S. 810, 820
Osborn, T. N., II 810, 610
Oster, G. 810, 820
Osterman, P. 820, 810
Ostry, S. 810, 820
Oswald, A. J. 830, 020
Oswald, R. A. 800, 200
Owen, J. D. 810, 820
Ozanne, R. W. 830, 820
Padilla, A. 820, 210
Pagenstecher, U. 800, 030
Palmer, J. L. 800, 910
Palomba, C. A. 810, 300
Palomba, N. A. 810, 820
Pascoast, E. 830, 040
Pannell, P. F. 820, 830
Papps, I. 840, 610
Parai, L. 800, 130
Parnes, H. S. 820, 810
Parsons, D. O. 820, 610
Passy, N. H. A. 840, 110
Payne, M. B. 800, 900
Pearce, J. E. 830, 810
Pearson, D. W. 830, 820
Pettchinis, S. G. 830, 820
Pencavel, J. H. 800, 020
Pendleton, E. C. 830, 820
Perles, S. P. 810, 820
Perline, M. M. 830, 820
Perlman, M. 840, 030
Perlman, R. W. 820, 810
Perloff, J. M. 800, 900
Perna, N. S. 800, 130
Perry, J. H. 820, 810
Persson-Tanimura, I. 810, 820
Pfefferbaum, R. 840, 060
Phananiramai, M. 840, 210
Phillips, C. N. 820, 940
Phillips, I. P. 810
Pierson, F. 820, 130
Pilavios, A. 850, 820
Plantes, M. K. 820, 310
Plotnick, R. D. 820, 910
Podgursky, M. J. 830
Polachek, S. W. 800, 200
Popkin, B. M. 850, 120
Porter, T. S. 810
Potter, J. E. 840, 110
Poulton-Callahan, C. 820, 320
Powel, J. H., Jr 800, 520
Prince, J. E. 830, 520
Prosper, P. A. 830, 820
Psacharopoulos, G. 850, 820
Pupp, R. L. 800, 900
Pursell, D. E. 840, 810
Quan, N. T. 830, 850
Quester, A. O. 820, 850
Quinn, J. F. 810, 850
Rabideau, P. F. 810, 020
Radakovic, G. 820, 940
Raffe, F. A. 810, 940
Ragan, J. F. 820, 810
Raimon, R. L. 820, 830
Raisian, J. 800, 210
Rallis, J. J. 830, 820
Rankin, C. A. 810, 850
Raschke, F. 800, 000
Ray, R. S. 810, 820
Raymond, R. D. 850, 020
Rea, S. A., Jr 800, 910
Reagan, B. B. 820, 920
Reder, M. W. 820, 830
Redwood, A. L. 820, 840
Reed, J. A. 820, 320
Reedy, T. W. 830, 610
Rees, A. E. 800, 220
Reflor, E. L. 820, 830
Reich, M. 800, 050
Reid, F. 800, 010
Reid, J. T. 810, 910
Reimers, C. W. 810, 910
Rence, C. C. 800, 910
Renner, D. L. W. 800, 600
Repetto, R. 840, 100
Reubens, B. G. 820, 810
Reynolds, H. 850, 020
Reynolds, M. O. 800, 020
Reynolds, R. R. 830, 820
Riach, P. A. 820, 020
Rice, W. V., Jr 830, 820
Rich, S. C. 800, 610
Richardson, S. 820, 720
Riddle, B. Z. 840, 530
Ridgel, G. T. 830, 820
Ritchie, W. G. 830, 210
Rives, N. W. 840, 940
Ro, K. 850, 840
Roberts, M. 800, 130
Roberts, R. D. 800, 900
Robinson, D. 820, 830
Robson, R. T. 800, 310
Roderick, R. D. 830, 820
Roland, N. D. 810, 940
Romine, L. E. 830, 820
Rondeau, C. 830, 820
Rosen, F. M. 820, 930
Rosen, H. 800, 810
Rosen, S. 800, 020
Rosen, S. J. 830, 810
Rosenberg, S. 800, 130
Rosenthal, G. D. 820, 830
Rosenthal, R. A. 800, 900
Rosenzweig, M. R. 800, 100
Rosko, M. D. 850, 530
Ross, C. G. 820, 120
Ross, R. T. 800, 720
Roetker, B. D. 820, 850
Rothbaum, M. 830, 820
Rothman, L. D. 800, 500
Rowe, M. 830, 510
Rowland, C. R. 850, 910
Rozen, M. E. 820, 120
Rubin, I. I. 830, 040
Rubin, M. 830, 820
Rudd, N. M. 850, 910
Rulison, M. V. E. 840, 700
Rungeling, B. S. 800, 910
Ruser, J. W. 820, 910
Russell, M. W. 820, 910
Rutman, G. L. 820, 120
Ruttenberg, S. H. 830, 810
Ryan, E. W. 830, 820

Ryan, P. 810, 010
Rycroft, R. S. 810, 820
Saalbach, W. F. 830, 010
Saben, S. 820, 810
Sachko, A. M. 810, 210
Sadowski, D. 810, 510
Saijadi, P. S. 810, 510
Salsburg, S. W. 830, 820
Sandell, S. H. 800, 320
Sandy, R. 810, 030
Santana, A. 830, 120
Santos, F. P. 800, 610
Sarb, P. J., Sr 840, A00
Saueracker, E. 850, 930
Sawahn, W. 810, 820
Sawhill, I. V. 820, 810
Sawtelle, B. A. 820, 610
Saywell, R. M., Jr 800, 900
Schachter, J. 800, 020
Schaefer, M. E. 850, 920
Schaeffer, P. 800, 900
Schaffer, B. K. 830, 030
Schapiro, M. O. 800, 040
Scheffler, R. M. 810, 850
Scherer, P. M. 800, 020
Scheuch, R. 830, 820
Schiller, B. R. 800, 910
Schlicht, E. 810, 020
Schmidt, C. T., Jr 830, 100
Schmidt, K. 820, 920
Schmidt, R. M. 850, 820
Schmidt, R. M. 840, 210
Schmitz, R. J. 810, 210
Schneider, K. B. 830, 510
Schnell, J. F. 830, 820
Schramm, C. J. 810, 830
Schrock, J. L. 800, 220
Schultz, T. P. 840, 820
Schumacher, A. R. 830, 820
Schwartz, A. 800
Schwartz, A. R. 830, 820
Schwartz, B. 820, 810
Schwartz, G. W. 830, 320
Schwartz, H. A. 800, 200
Scitovsky, A. A. 800, 000
Scott, A. M. 820, 130
Scott, C. E. 810, 000
Scott, L. C. 810, 940
Scoville, J. G. 820, 830
Scuka, K. M. 830, A00
Seeborg, M. C. 820, 810
Segal, M. 800, 610
Segal, M. J. 800, 910
Selver, D. A. 840, 940
Seltzer, G. O. 820, 830
Sen, J. 830, 820
Serow, W. J. 840, 940
Shackelford, J. A. 800, 900
Shaeffer, R. G. 800, A00
Shaffer, L. J. 850, 020
Shapiro, D. 800, 840
Shapiro, P. A. 800
Sharir, S. 810, 920
Sharma, V. P. 840, 210
Shaw, K. L. 820, 850
Shaw, L. B. 810, 840
Shaw, S. O. 830, 820
Shea, J. R. 810, 820
Shearer, C. L. 800, 600
Shearer, J. C. 800, 110
Sheingold, S. H. 810, 820
Sheldon, G. M. 800, 200
Shepard, A. J. 800, 210
Shih, C. Y. 820, 850
Shinevar, P. O. 830, 820
Shister, J. 830, 820
Shulenburger, D. E. 820, 830
Siebert, W. S. 830, 850
Siegenthaler, L. A. 820, 910
Silber, J. G. 840, 120
Simler, N. J. 820, 010
Simmons, G. B. 840, 120
Simmons, J. L. 810, 710
Simon, J. L. 840, 530
Sinha, R. P. 820, 830
Siow, A. 800
Siragaldin, I. 800, 120
Siskind, F. B. 820, 810
Skidmore, F. 810, 910
Skidmore, M. H. 810, 710
Skinner, G. S. 820, 020
Skoro, C. L. 810, 820
Skrable, B. H. 810, 820
Skraly, E. B. 810, 820
Slaysman, K. S. 810, 610
Sloan, F. A. 810, 850
Smith, A. W. 830, 010
Smith, B. A. 820, 620
Smith, D. C. 820, 130
Smith, H. W. 800, 220
Smith, J. P. 820, 840
Smith, J. T. 840, 120
Smith, L. H. 810, 020
Smith, R. E. 800, 200
Smith, R. E. 800, 100
Smith, R. F. 830, 060
Smith, S. K. 840, 120
Smith, S. P. 820, 810
Smith, W. S. 800, 300
Smoker, R. E. 810, 210
Snyder, N. M. 820, 320
Snyder, R. A. 830, 910
Soderstrom, L. A. 820, 910
Soffer, B. 820, 830
Solberg, E. J. 810, 910
Solle, R. J. 800, 620
Solmon, L. C. 850, 810
Solnick, L. M. 810, 820
Sorkin, A. L. 810, 910
Sorrentino, D. 800, 400
Sparrough, M. E. 830, 520
Sparrow, D. G. 830, 820
Spellman, W. E. 830, 030
Spencer, B. G. 800
Spero, N. 830, 620
Spiegelman, R. G. 800, 910
Spinanger, D. 800, 120
Spitz, H. 800, 050
Spitz, R. S. 820, 830
Spizman, L. 820, 830
Stager, D. A. A. 820, 810
Staller, J. M. 830, 820
Stark, H. F. 830, 510
Staudohar, P. D. 830, 820
Stein, B. 820, 910
Stein, K. L. 820, 830
Steinberg, E. I. 810, 130
Stephan, P. E. 850, 810
Stephanson, E. M. 810, 820
Stephenson, S. P. 800, 210
Stern, D. 810, 820
Stern, J. L. 830, 820
Stevens, C. M. 830, 820
Stevens, D. W. 820, 130
Stevens, G. J. 810, 510
Stevenson, W. L. 810, 210
Stewart, C. D. 820, 810
Stewart, G. T. 810, 110
Stewart, J. P. 810, 320
Stich, J. G. 810, 850
Stieber, J. 830, 820
St James-Perry, H. L. 800, 900
St Laurent, J. 810, 830
Stoikov, J. H. 800, 610
Stoltz, J. F. 810, 100
Stolzenberg, R. M. 800, 210
Stone, C. E. 800, 520
Stone, G. L. 800, 000
Strand, K. T. 810, 830
Stregevsky, B. M. 820, 610
Strober, M. H. 820, 810
Stromsdorfer, E. W. 800, 850
Sula, L. J. 810, 930
Svelkauskas, C. D. 800, 100
Svejnar, J. 800, 050
Swartwout, J. E. 810, 200
Swartz, B. K. 820, 320
Swartz, C. 840, 100
Sweeney, M. J. 810, 840
Sweetland, D. P. 810, 030
Swidler, S. 840, 520
Swint, J. M. 800, 100
Tabbarah, R. B. 840, 120
Tabbush, V. 810, 120
Takahara, R. 850, 910
Tannen, M. 800, 200
Tannery, F. J. 820, 810
Taubman, P. J. 850, 320
Taylor, A. G. 830, 030
Taylor, B. J. 800, 020
Taylor, D. 800, 620
Taylor, P. A. 810, 840
Taylor, T. A. 830, 010
Taylor, T. J. 810, 840
Teicher, J. 810, 830
Telia, A. J. 800, 200
Telling, F. W. 810, 110
Thaler, H. H. 830, 910
Theeuwes, J. 800, 210
Theroux, R. P. 820, 010
Thimm, A. L. 810, 830
Thomas, G. W. 800, 210
Thompson, A. R. 800, 000
Thompson, H. S. 820, 610
Thonstad, T. 800, 410
Thorne, A. C. 850, 920
Thornton, C. V. D. 810, 930
Thornton, R. J. 820, 830
Thurow, L. C. 800, 320
Tideman, T. N. 820, 320
Tinney, R. 810, 820
Tirado de Alonso, I. G. 850, 220
Toikka, R. S. 820, 810
Tomes, N. 800, 840
Torok, S. J. 820, 710
Triplett, J. E. 800, 220
Tripp, L. R. 830, 820
Troy, L. 830, 820
Tuckman, B. H. 810, 610
Turchi, B. 840, 020
Turkington, D. J. 830, 410
Turner, J. A. 810, 910
Turvey, R. 820, 630
Tychsen, S. L. 830, 850
Tyson, K. W. 800, 200
Tyson, R. J. 800, 320
Udis, B. 820, 620
Uekermann, M. N. 810, 430
Uhalde, R. J. 800, 900
Ulman, L. 830, 820
Utsumi, Y. 800, 000
Vaccaro, V. 820, 220
Vanderberg, R. D. 830, 910
Van Der Hoek, M. P. 820, 320
Vanderkamp, J. 820, 310
Van Loo, M. F. 840, 320
Vass, S. T. 850, 120
Vavrichek, B. 820, 210
Vega-Jarrin, E. V. 830, 010
Venti, S. F. 810, 820
Ventura, S. J. 840, 220
Vermeulen, B. T. 820, 120
Vernon, T. T. 830, 220
Verry, D. W. 850, 820
Vieira da Cunha, P. 800, 200
Vijverberg, W. P. M. 840, 210
Vining, D. R., Jr 840, 220
Virgo, J. M. 810, 820
Viscusi, W. K. 820, 020
Visile, J. 800, 020
Von Rabenau, B. B. 820, 930
Voos, P. B. 830, 810
Wachtel, H. M. 800, 020
Wachter, M. L. 800, 300
Wagner, A. P. 850, 920
Wagner, D. P. 800, 210
Wagner, M. 820, 040
Wai, H. S. 800, 900
Waldenberg, A. L. 810, 820
Waldman, E. 810, 220
Wallace, P. A. 800, 000
Walsh, W. D. 820, 830
Walsh, W. J. 830, 610
Walther, R. J. 800, 200
Wampler, C. E. 800, 600
Wandner, S. A. 810, 820
Wanik, B. 820, 540
Ward, W. A. 810, 520
Warner, A. W. 830, 610
Warren, R. S. 820, 320
Wascher, W. L., III 800, 210
Weber, C. T. 830, 930
Weber, G. I. 850, 910
Weiler, W. C. 800, 210
Weinberg, N. 830, 110
Weiner, S. E. 800, 300
Weinstein, P. A. 800, 020
Weintraub, A. R. 800, 820
Weintraub, N. A. 830, 820
Weiskopf, W. J. 830, 820
Weiss, A. 800, 020
Weiss, R. D. 800, 320
Weiss, Y. 810, 000
Welch, F. 820, 810
Welch, S. W. 820, 610
Welland, D. A. 820, 020
Wendling, W. 820, 830
Werner, J. L. 810, 910
Wertheimer, R. F. 840, 910
Wessels, W. J. 820, 830
Westergaard, N. 810, 820
White, D. J. 830, 820
White, M. D. 820, 830
White, W. D. 800, 040
Whiteman, J. L. 850, 620
Wiesenburg, A. G. 810, 910
Willauer, E. T. 820, 720
Willekens, F. J. 840, 940
Williams, A. D. 840, 810
Williams, C. G. 820, 830
Williams, D. C. 810, 820
Williams, W. E. 820, 900
Willing, S. S. 810, 630
Willis, R. J. 840, 810
Wilke, R. J. 810, 210
Wilson, F. S. 850, 310
Wilson, R. M. 810, 820
Wilson, S. F. 830
Wilson, W. W. 840, 920
Winakur, I. 850, 410
Windham, D. M. 850, 320
Winegarden, C. R. 840, 110
Winkler, D. R. 850, 900
Wirpel, S. W. 830, 850
Wislewski, S. C. 800, 830
Witkowski, E. H. 850, 110
Witney, F. 830, 820
Wolfe, B. L. 800, 020
Wolff, E. N. 820, 620
Wolin, C. M. 840, 820
Wolitz, L. B. 800, 900
Wolpin, K. I. 800, 000
Wood, W. D. 800, 600
Woodbury, S. A. 800, 000
Wool, H. 810, 820
Wool, M. B. 800, 810
Worrall, J. D. 820, 630
Wright, E. E. 800, 500
Wrong, E. G. 810, 830
Yamada, T. 800, 100
Yamaguchi, M. 840, 710
Yamashita, S. 840, 110
Yashiro, N. 820
Yett, D. E. 810, 820
Young, R. C. 810, 110
Youtsler, J. S. 830, 820
Zabala, C. A. 830, 630
Zabor, S. L. 820, 010
Zaidi, M. A. 800, 900
Zalokar, C. 800, 040
Zangl, P. 820, 100
Zapoleon, M. W. 800, 000
Zarkin, G. A. 810, 820
Zeller, F. A. 810, 820
Zellner, H. 800, 020
Zick, C. D. 850, 920
Ziderman, A. 810, 820
Zimmermann, K. F. 840, 920
Ziskind, D. 830, 110
Zito, B. E. 830, 200
Zoloth, B. S. 850, 920
Zucker, A. 820, 210
Zuckerman, S. 800, 210
Zumbura, G. 810, 820

900 WELFARE PROGRAMS; CONSUMER ECONOMICS; URBAN AND REGIONAL ECONOMICS

910 WELFARE PROGRAMS
920 CONSUMER ECONOMICS

Abdel-Ghany, M. 920
Abelson, P. W. 930, 320
Adams, J. E. 940, 630
Adams, J. F. 900, 800
Adams, R. G. 940, 800
Ahlbrandt, R. S. 930, 910
Akita, T. 930
Alexis, M. 930, 820
Allen, A. W. 920, 030
Allen, G. H. 910, 220
Allen, J. W. 930, 940
Alonso, W. 930, 940
Anas, A. 930, 110
Anderson, B. B. 930, 520
Andreano, R. L. 900, 120
Andrulis, J. A. 930, 320
Anselin, L. E. 940, 210
Antle, L. G. 940, 720
Arnold, R. K. 940, 220
Aronson, S. J. 910, 320
Arroyo, E. J. 930, 320
Asofsky, A. A. 910, 510
Atkins, A. S. 940, 210
Ault, T. A. 910
Avio, K. L. 900, 000
Axinn, J. M. 910, 930
Ayodeji, O. 930, 120
Ayres, R. W. 920, 120
Bagby, D. G. 930, 940
Bagwell, J. A. 940, 840
Baily, M. A. 910, 110
Baird, C. A. 940, 320
Balkhy, H. O. 900, 400
Balkin, S. M. 930, 910
Barnett, H. C. 910, 310
Barrington, E. W. 920, 820
Bartlett, R. 930, 320
Basiotis, P. P. 900, 800
Bates, T. 930, 310
Bathish, N. A. 930, 120
Baum, D. N. 930, 320
Bausch, J. M. 940, 210
Bawden, D. L. 910, 810
Bayless, M. E. 930, 010
Bays, C. W. 900, 610
Beane, L. E. 930, 900
Bechdolt, B. V. 940, 020
Beck, R. G. 910, 940
Beebout, H. 910, 820
Bell, C. S. 910, 800
Bendick, M. 900, 800
Bendwell, A. 930, 940
Benson, B. L. 940, 610
Bentivegna, V. 930, 940
Bentkover, J. D. 910, 000
Bentley, J. M. 910, 010
Benz, G. A. 930, 810
Berki, S. E. 900, 600
Berkowitz, M. 910, 820
Bernstein, B. 910, 930
Bernstein, R. E. 930, 020
Bernsten, B. P. 940, 130
Bethune, G. C. 930, 320
Beutler, I. F. 920, 640
Bevins, R. J. 900, 700
Beyers, W. B. 940, 100
Bias, S. S. 930, 310
Biesdorf, H. B. 920, 030
Biggs, J. H. 910, 920
Bilheimer, L. T. 910, 220
Birdzell, O. K. 930, 320
Birnbaum, H. G. 910, 850
Birnbaum, H. M. 920, 010
Bish, R. L. 930, 320
Bishop, C. E. 910, 810
Bittman, R. A. 900, 500
Bivens, G. E. 920, 850
Blaustein, S. J. 910, 820
Blodgett, F. C. 930, 830
Blomquist, G. C. 900, 720
Bloom, M. R. 930, 520
Blowers, C. W. 930, 720
Boan, J. A. 910, 720
Boaz, R. F. 910, 800
Bobrovitch, D. 940, 720
Boeh, J. M. 910, 220
Bohigas, L. 910
Bohm, R. A. 930, 720
Boland, J. P. 900, 800
Bolton, R. E. 940, 720
Bonham, J. M. 930, 130
Booth, D. E. 930, 030
Borukhov, E. 930, 320
Borzilleri, T. C. 900, 800
Bossard, E. G. 930, 320
Bowers, J. S. 920
Bowman, H. W. 930, 210
Boyd, J. W. 920, 210
B'Racz, I. 930, 400
Bradbury, K. L. 930, 320
Braid, R. M. 930, 720
Bretz, J. S. 910, 520
Brinker, P. A. 910, 820
Brophy, T. P., Jr 910, 920
Brovender, S. 920, 840
Brown, B. 930, 020
Brown, D. M. 910, 020
Brueckner, J. K. 930, 320
Brunet, J. M. 910, 510
Bryant, W. K. 900, 800
Buchberger, T. J. 910
Budin, M. 930, 630
Burk, M. C. 920, 000
Burnell, J. D. 930, 720
Burns, E. M. 910
Burns, L. S. 940, 930
Burright, B. K. 930, 810
Buttler, H. 930, 940
Bykoski, L. M. 940, 120
Caballes, A. Z. 940, 930
Callan, A. J. 930, 810
Call, S. T. 930, 020
Caniglia, A. S. 930, 210
Cannon, J. B. 940, 730
Capozza, D. R. 930, 520
Caprio, M. M. 930, 210
Carney, K. 900, 210
Carruthers, N. E. 930, 610
Case, F. E. 930, 020
Casey, M. T. 930, 310
Caswell, R. J. 910, 610
Centonze, A. 930, 320
Cesario, F. J. 900, 720
Chalmers, J. A. 940, 730
Chambers, J. G. 910, 820
Chambers, W. J. 930, 320
Champion, H. E. 920, 220
Chandler, C. A., Sr 930, 220
Chang, O. 920, 210
Charlton, M. C. 940, 210
Chase, E. P. 900
Chatterji, M. 940, 210
Chen, C. 940, 840
Cherlow, J. R. 930, 220
Chinitz, B. 930, 940
Chirikos, T. N. 910, 810
Christiansen, J. B. 900, 610
Chung, J. H. 930, 210
Churchill, A. A. 930, 100
Clapp, J. M. 930
Clark, G. N. 930, 520
Clemhout, S. 920, 930
Clemmer, R. B. 900, 320
Cloninger, D. O. 910, 520
Cobb, S. A. 900, 000
Coe, R. D. 910, 320
Coelen, S. P. 940, 720
Cohen, A. L. 910, 820
Cohen, L. 930, 940
Cohen, W. J. 910, 850
Cohn, E. 910, 850
Collier, G. A. 940, 060
Collignon, F. C. 900, 810
Collins, T. B. 930, 940
Colman, S. B. 930, 940
Colwell, P. F. 930, 940
Colwell, R. C. 930, 840
Conlo, G. 930, 940
Conover, C. J. 910, 130
Conway, R. S., Jr 940, 210
Coogan, M. G. 910, 800
Cook, P. J. 930, 910
Cooke, T. W. 930, 020
Coppieters, P. A. 940, 060
Cowan, R. S., Jr 940, 020
Cox, B. C. 930, 520
Cox, M. A. 930, 320
Coyte, P. C. 910, 810
Craig, S. G. 900, 830
Crampton, G. R. 930, 210
Crane, R. D. 930, 320
Creighton, L. B. 920, 010
Cremer, H. S. 940, 500
Crone, T. M. 930, 320
Crowe, B. S. 930, 110
Crowe, D. A. 930, 920
Crowe, D. M. 940, 640
Crowell, W. H. 930, 320
Cumberland, J. H. 940, 720
Curran, C. 930, 210
Cushing, B. J. 930, 940
Czamanski, D. 930, 940
Czamanski, S. 940, 630
Daellenbach, L. A. 930, 060
Dale-Johnson, D. T. 930, 520
Daniel, R. P. 930, 610
Daniels, L. D. 930, 320
Danziger, S. H. 900, 220
Dardis, R. 920, 910
Davenport, R. C. 930, 940
Davidson, H. A. 930, 520
Davies, H. B. 920, 310
Davis, K. 900, 600
Davis, S. 930, 010
Dawson, R. L. 930, 850
Dean, R. D. 930, 940
Deaton, A. S. 920, 200
Dedekam, A., Jr 940, 210
Del Rossi, J. A. 910, 810
De Laky, B. R. 910
Demello, P. C. 930, 040
Denzin, C. E. 920, A00
Depass, R. E. 940, 130
Derrick, F. W. 920, 200
Desalvo, J. S. 930, 910
Deutch, J. 910, 510
Deutsmann, E. P. 940, 110
Diamond, D. B., Jr 930, 940
Dietz, A. L. 940, 720
Dimasi, J. A. 930, 210
Dipasquale, D. M. 930, 320
Doerring, P. B. 900, 700
Domazlicky, B. R. 940, 210
Doti, J. L. 930, 210
Dotterweich, D. P. 930, 940
Dougherty, L. A. 930, 940
Douglas, E. 920, 530
Douthitt, R. A. 920, 820
Dowall, D. E. 930, 940
Downing, D. A. 910, 610
Downs, A. 930, 110
Drake, K. 910, 810
Dreessen, E. A. J. 920, 620
Drennan, M. P. 930, 940
Ducharme, R. G. 930, 940
Duncan, R. S. 930, 320
Dunkelberg, W. C. 920, 210
Dunlop, D. W. 910, 110
Dunsing, M. M. 920, 840
Durbin, E. F. M. 900, 800
Durden, G. C. 930, 010
Durham, F. W. 930, 840
Dutton, R. A. 940, 640
Earle, J. A. 930, 320
Eastwood, D. B. 920, 210
Eckert, J. K. 930, 510
Edberg, A. L. 930, 020
Eddin, S. 940, 110
Edel, M. D. 930, 120
Edelstein, R. H. 930, 200
Edwards, K. P. 920, 020
Egand, L. M. 930, 810
Eggers, F. J. 930, 400
Eichenholz, J. 900, 600
Eisenhut, J. 930, 940
Eisner, B. 920, 930
Elison, R. W. 930, 940
Emerling, E. G. 930, 940
Emerson, M. J. 940, 210
Engelmann, P. H. 910, 810
Englund, P. 930, 320
Ericson, H. E. 930, 320
Eskowitz, H. J. 930, 610
Etheredge, L. M. 910, 720
Ethridge, V. K. 920, A00
Fagerlund, E. A. 930, 320
Faies, R. L. 930, 040
Falick, A. J. 930, 520
Fallis, G. B. 930, 320
Feigenbaum, B. 910, 610
Fein, R. 910, 800
Feldman, M. M. A. 930, 110
Feldstein, P. J. 913, 610
Fethke, C. C. 910, 850
Finan, K. C. 910, 930
Fischel, W. A. 930, 320
Fisher, P. 910, 800
Fishkind, H. 940, 130
Fitch, L. C. 930, 320
Fitzmaurice, J. M. 910, 210
Fletcher, J. A. 900, 000
Fogarty, M. S. 930, 940
Follain, J. R. 900, 300
Forbush, D. R. 940, 840
Ford, E. J. 930, 320
Ford, M. L. 940, 510
Forsyth, P. J. 930, 610
Foster, R. W. 910, 520
Fox, A. 910, 220
Fox, M. M. 930, 210
Fox, R. T. 910, 010
Fraley, C. E. 930, 020
Frank, C. 940, 210
Frank, R. G. 900, 800
Fratrik, M. R. 940, 600
Fredericks, P. C. 940, 100
Freiricha, B. H. 930, 320
Frey, D. E. 910, 810
Friedman, J. 900, 100
Frishman, A. I. 930, 120
Fritz, R. G. 930, 940
Fujita, M. 930, 110
Furino, A. 930, 620
Furman, J. L. 930, 320
Gaffney, J. G. 910, 010
Galster, G. C. 930, 820
Gappert, G. 930, 220
Gardner, J. L. 930, 020
Garfinkel, I. 910, 810
Garrett, M. A. 940, 930
Gasperi, K. C. 910, 440
Gaughen, D. F. 940, 610
Geistfeld, L. V. 920, 910
Geraci, D. V. 930, 020
Gerard, R. 930, 840
Gerking, S. D. 940, 210
Gerner, J. L. 920, 840
Getz, M. 930, 320
Getzen, T. E. 913
Giarratani, F. 940, 930
Gill, H. L. 930, 940
Gillette, D. G. 900, 600
Gilmore, J. S. 940, 620
Ginsburg, P. B. 910, 610
Gladstone, R. 930, 940
Glaze, R. S. 930, 940
Glickman, N. J. 930, 210
Golay, J. 930
Goldberg, D. C. 900, A00
Goldberg, K. 930, 220
Goldberg, M. A. 930, 940
Goldberg, R. H. 930, 320
Goldberg, S. P. 910
Goldfarb, D. L. 910
Goldfein, J. 910, 220
Goldmann, H. 910, 820
Goldner, W. 930, 210
Goldstein, G. S. 930, 800
Goldstein, H. A. 940, 820
Golladay, F. L. 910, 110
Gonzalez, J. E. 940, 930
Goodman, A. C. 930, 220
Goodman, J. L., Jr 930, 840
Goolsby, W. C. 930, 130
Gordon, J. G. B. 910, 930
Gordon, M. S. 910, 820
Grana, J. M. 910, 610
Graves, K. K. 920, 840
Graves, P. E. 930, 020
Grebler, L. 930, 520
Green, R. D. 930, 040
Greene, T. F. 910, 320
Greenfield, S. J. 940, 220
Greenspan, N. T. 900, 810
Greenwald, S. E. 900, A00
Greenwood, M. J. 930, 840
Griffin, D. W. 920, 210
Griffin, J. B. 930, 310
Grigsby, W. G. 930, 940
Grimes, A. R., Jr 940, 130
Grimes, D. R. 940, 820
Gronberg, T. J. 930, 320
Grossman, M. 910, 020
Gruen, A. C. 930, 620
Gruen, C. 930, 940
Gruenstein, J. M. L. 930, 940
Grunloh, J. J. 940, 320
Gueron, J. M. 910, 810
Gunther, W. D. 940, 630
Gustely, R. D. 940, 320
Guterman, S. 910, 930
Gutowski, M. F. 930, 320
Guy, D. C. 930, 940
Hafstrom, J. L. 920, 210
Hagens, J. B. 940, 210
Hakim, S. 940, 930
Hall, C. S. 930
Hall, P. D. 940, 930
Hambleton, J. W. 920, 800
Hambright, W. E. 940, 220
Hamer, A. M. 930, 050
Hamilton, B. W. 930, 320
Hamilton, K. L. 910, 630
Hamilton, P. R. 910
Hampe, J. 930, 940
Hanna, S. 920, 210
Hannes, L. E. 900, 800
Hansen, N. M. 940, 930
Hanson, J. A. 930, 610
Hardman, A. M. 930, 320
Harrington, J. W., Jr 940, 620
Harris, B. N. 930, 320
Harris, C. C. 940, 930
Harris, R. 910, 320
Harrison, D. 930, 720
Hartmann, G. B. 940, 930
Harvey, A. S. 900, 220
Hasson, D. S. 930, 940
Hau, A. J. 910, 800
Haurin, D. R. 930, 320
Hauser, R. J. 910, 820
Hausrath, L. L. 930, 940
Hayes, F. O. 930, 320
Heeden, A. E., Jr 910, 210
Hefferan, C. 920, 220
Heffley, D. R. 930, 020
Heilbrun, J. 930, 320
Heinberg, J. D. 930, 320
Hekman, J. S. 940, 630
Henderson, J. V. 930, 320
Hendler, R. 930, 940
Hendrickson, C. 930, 210
Henke, C. J. 910, 810
Henry, M. S. 940, 210
Henson, S. E. 930, 720
Herndon, M. B. 930, 200
Herrick, T. R. 940, 110
Herrmann, R. O. 920, 710
Herzog, H. W. 940, 840
Hester, J. B. 940, 210
Hewings, G. J. D. 940, 930
Hicks, B. C. 910
Hinson, W. R. 930, 120
Hinz, M. M. 930, 940
Hirsch, W. Z. 930, 320
Hite, J. C. 940, 720
Hnatchuk, J. 920, 210
Hoagland, G. W. 910, 710
Hobble, R. A. 910, 820
Hoch, I. J. 930, 210
Hochman, O. 930, 020
Hoffer, S. 930, 110
Hoffman, M. 930, 840
Hoffman, N. 900, 320
Holdowsky, M. M. 920, 210
Holleb, D. B. 930, 910
Hollenbeck, K. 910, 210
Holliday, R. E. 940, 210
Holmans, S. K. 910, 840
Holmer, M. R. 910, 320
Holt, H. G. 913, 820
Honig, M. 910, 810
Horgan, C. M. 920, 840
Hornbrook, M. C. 910, 630
Hough, D. E. 910, 320
Houle, R. 940, 840
Howenstine, E. J. 930, 820
Hu, J. C. 930, 210
Huegy, C. W. 930, 220
Hughes, G. A. 930, 120
Hum, D. 910, 810
Hunt, T. L. 940, 210
Hunter-Holmes, J. C. 920
Hurter, A. P. 940, 520
Hushak, L. J. 940, 720
Huskey, T. L. 940, 840
Huttman, J. P. 930, 040
Hydock, M. F. 930, 320
Ingene, C. A. 930, 530
Ingram, G. K. 930, 210
Ippolito, P. M. 920, 610
Isakson, H. R. 930, 320
Isard, W. 940, 020
Ito, H. H. 900
Izraeli, O. 930
Jackson, J. D. 940, 210
Jackson, R. W. 940, 610
Jacobs, E. E. 920
Jacobs, S. S. 930, 940
Jansson, J. O. 930, 010
Jelavich, M. S. 930, 940
Jenkins, S. J. 920, 940
Jeske, W. P. 940, 130
Jimenez, E. 930, 110
Joffe, J. 910, 630

Johnson, E. K., Jr 940, 120
Johnson, M. S. 930, 320
Jolda, R. E. 930, 940
Jones, B. G. 940, 930
Jones, D. D. 930, 320
Jones, R. H. 930, 320
Jones, S. B. 920, 530
Joseph, H. 910, 210
Jud, G. D. 930, 940
Kain, J. F. 930, 820
Kaluzny, R. L. 910, 930
Kanemoto, Y. 930, 020
Kapteyn, A. 920, 200
Karatjas, N. 900, 320
Karg, G. 920, 210
Karach, C. 940, 310
Kartman, A. E. 930, 940
Kasoff, M. J. 930, 940
Katona, G. 920, 020
Katsuragi, K. 940, 030
Katzoff, J. M. 910, 810
Kau, J. B. 930, 940
Kavanaugh, M. 940, 720
Kehrer, B. H. 910, 610
Kehrer, K. 910, 810
Keil, S. R. 930, 940
Keintz, R. M. 910, 320
Kelly, K. R. 930, 220
Kepner, B. F. 930, 940
Kern, C. R. 930
Kershaw, J. A. 910, 850
Kerton, R. R. 920, 600
Kessler, A. 910, 810
Keyserling, M. D. 910, 810
Kickham, T. M. 910, 840
Kiddie, R. C. 940, 110
Kiefer, D. 930, 210
Kievat, I. M. 940, 930
Kim, S. 940, 110
King, A. T. 930, 310
Kinsey, J. 920, 910
Kirk, R. J. 930, 940
Klarman, H. E. 900, 320
Klein, R. E. 910, 010
Knapp, J. L. 940, 320
Knapp, M. R. J. 910, 810
Knox, H. W. 900, 100
Kocher, L. A. 920, A00
Koeppel, M. 940, 930
Kohlhase, J. E. 930, 320
Kong, C. M. 930, 210
Korbach, R. J. 940, 320
Korbel, J. J. 910, 000
Kort, J. R. 940, 210
Kottis, A. P. 900, 020
Kottis, G. C. 930, 940
Kouyoumdjian, H. E. 910, A00
Kowalsky, S. R. 940, 110
Kraft, G. 900, 600
Kraft, J. 930, 210
Krashinsky, M. 910, 320
Krasner, M. I. 900, 800
Kraus, M. 930, 020
Kriedel, T. 910, 200
Krim, J. C. 930, 210
Krohm, G. C. 930, 720
Kroll, H. N. 930, 940
Krumme, G. 940, 610
Kunreuther, H. C. 920, 610
Kurre, J. A. 940, 300
Laird, W. E. 940, 400
Lairson, D. R. 910
Laitila, E. E. 930, 940
Lakshmanan, T. R. 930, 940
Lambrinos, J. 910, 810
Lanahan Jr, T. J. 920, 220
Lande, P. S. 940, 130
Landefeld, J. S. 910, 720
Lando, M. E. 910, 220
Lane, S. 920, 110
Lange, M. D. 930, 850
Langford, T. W. 940, 720
Latham, W. R. 900, 210
Latimer, M. W. 910, 830
Lave, C. A. 930, 800
Laverty, P. T. 930, 310
Lazear, V. A. 920, 210
Lee, M. J. 930, 320
Lee, A. J. 910, 800
Lee, D. 930, 020
Lee, K. S. 930, 820
Lee, M. 920, 910
Lee, R. H. 910, 320
Lee, S. M. 920, 010
Lefebvre, M. P. 910, 320
Leigh, W. A. 930, 220
Leimer, D. R. 910, 820
Levasseur, K. D. 930, 320
Leven, C. L. 930, 940
Leveson, I. F. 900, 600
Levy, S. 940, 630
Lew, J. A. 940, 110
Lewis, W. C. 930, 720
Lewit, E. M. 910, 800
Li, H. 920, 000
Li, M. M. 930, 210
Lichty, R. W. 940, 060
Lipner, J. K. 930, 810
Lipscomb, J. 910, 210
Lloyd, C. B. 910
Lo, F. 940, 110
Loikkanen, H. A. 930, 820
Lowell, L. 930, 320
Lowell, R. 910, 820
Luczyszyn, A. M. 930, 320
Luft, H. S. 910, 800
Luke, R. D. 910, 000
Lundman, S. B. 910, 320
Lyall, K. C. 930, 310
Lynch, J. 920, 940
Lynch, L. K. 940, 220
Lynch, M. P. 920, 610
Lyon, D. W. 930, 910
Machnic, J. A. 930, 320
Mack, R. P. 920, 020
MacMillan, J. A. 940, 700
Maeda, N. 910, A00
Magrabi, F. M. 920, 850
Mahan, G. P. 920, 320
Mahoney, B. 900, 220
Mahoney, W. M. 910
Makholm, J. D. 930, 210
Malec, B. T. 913, 320
Malpezzi, S. 930, 400
Mandel, A. S. 930, 320
Mandell, L. 920, 310
Mankin, W. B. 930, 710
Manley, R. E. 930, 030
Mann, B. D. 930, 820
Mansell, R. L. 940, 210
Marcus, M. J. 930, 940
Mark, J. H. 930, 940
Markowski, M. P. 940, 210
Marlowe, J. 920
Martin, R. C. 930, 940
Maslove, A. M. 930, 320
Mathur, V. K. 930, 940
Mattila, J. M. 930, 940
Maurer, K. M. 910, 210
Maxwell, P. 940, 010
Mayer, N. S. 930, 320
Maynard, A. K. 910, 610
Maynes, E. S. 920, 220
Mayo, S. K. 900, 210
Mazek, W. F. 940, 210
McCall, N. 910, 920
McCallum, J. D. 940, 930
McCarthy, P. S. 930, 210
McCarthy, T. R. 913, 020
McCullick, J. J. 940, 020
McCulloch, L. C. 940, 930
McDermott, J. M. 930, 210
McDevitt, I. 930, 130
McDonald, J. F. 930, 810
McDonnell, M. J. 930, 840
McDougall, G. S. 930, 320
McGillivray, R. G. 930
McGough, D. T. 930, 840
McGuire, C. C., Jr 930, 310
McGuire, J. M. 930, 320
McGuire, P. A. 930, 310
McHugh, H. F. 920, 710
McKee, D. L. 900, 100
McMahan, J. 930, 940
McMenamin, P. 913, 800
McMillen, D. P. 930, 210
McPheters, L. R. 930, 310
Mead, A. C. 940, 840
Meadows, G. R. 930, 320
Mehay, S. L. 930, 320
Mengle, D. L. 930, 610
Mera, K. 940, 930
Merchant, M. M. 920, 000
Merriam, I. C. 910, 220
Merrill, S. R. 930, 910
Meunier, M. F. 940, 120
Miernyk, W. H. 940, 210
Miller, A. 930, 120
Miller, D. R. 930, 630
Miller, G. W. 930, 910
Miller, J. P. 940, 110
Miller, L. 910, 800
Miller, P. W. 930, 320
Miller, R. K. 930, 210
Milliman, J. W. 930, 720
Millonzi, J. C. 930, 060
Mills, E. S. 930, 020
Milne, R. G. 910, 000
Miners, L. A. 910, 210
Minte, H. 920, 400
Miszynski, D. J. 930, 320
Mitchell, J. W. 940, 930
Moffitt, R. A. 900, 800
Mohan, R. 930, 110
Monheit, A. C. 900, 800
Montanaro, E. G. 930, 940
Mook, S. A. 930, 940
Moomaw, R. L. 930, 940
Moon, M. 900, 320
Moor, J. R., Jr 930, 210
Morresle, J. C. 910, 200
Morris, J. R. 930, 610
Morrisey, M. A. 900, 610
Mors, W. P. 920, 520
Morse, G. W. 930, 940
Morse, R. L. D. 920, 530
Moser, D. A. 930, 940
Moskowitz, M. E. M. 920, 130
Moss, W. G. 930, 020
Moyer, M. E. 910, 840
Mueller, C. D. 910, 020
Mueller, C. F. 940, 210
Mullendore, W. E. 940, 930
Mullin, S. P. 910, 820
Munro, D. R. 910, 630
Murphy, S. T. 940, 210
Murray, J. A. 930, 940
Murray, J. M. 940, 830
Musgrove, P. 920, 120
Muth, R. F. 930, 020
Myers, F. E. 940, 320
Nakosteen, R. A. 940, 930
Naroff, J. L. 930, 910
Naumes, M. J. 930, 920
Neenan, W. B. 930, 320
Neff, P. 930, 910
Nelson, G. L. 900, 220
Nelson, K. P. 930, 840
Neutze, M. 930, 940
Newell, H. F. 930, 940
Newhouse, J. P. 910, 850
Newman, M. 940, 930
Newsom, R. T. 930
Nicholas, J. C. 930, 940
Nicol, H. O. 910, 020
Nicosia, F. M. 920, 220
Niedercorn, J. H. 940, 930
Niehaus, R. D. 940, 720
Nielsen, D. A. 930, 320
Nierenberg, N. 940, 930
Nilsson, B. J. 900, 320
Nilsson, C. A. 920, 520
Noe, N. N. 930, 320
Nord, S. 930, 320
Norton, R. D. 930, 320
Nottingham, D. L. 913, 610
Noyes, J. S. 930, 800
Nunez, F. 910, 060
Nyman, J. A. 913, 400
O'Donoghue, P. 900, 600
O'Grady, T. F. 920, 530
Ohls, J. C. 930, 320
Ohsfeldt, R. L. 930, 020
Olson, G. 900, 000
Orr, L. L. 910, 820
Orzech, A. W. 940, 840
Oster, C. V., Jr 930, 620
Ostman, H. E. 930, 630
Ostro, B. D. 930, 720
Ozanne, L. J. 930, 910
Pack, J. R. 930, 940
Padon, C. A. 910, 810
Pagano, M. A. 900, 300
Paglin, M. 930, 020
Palmquist, R. B. 930, 720
Palumbo, G. M. 930, 940
Papageorgiou, G. J. 930, 940
Paraskevopoulos, C. C. 930, 110
Parcells, R. J. 930, 210
Parkay, K. K. 920, 910
Patterson, P. D. 900, 730
Pearson, B. K. 940, 130
Penz, A. J. 930, 620
Perez, H. 920, 130
Petersen, D. N. 940, 220
Peterson, D. H. 940, 210
Peterson, J. M. 940, 820
Petrulis, M. F. 940, 210
Peyton, M. S. 930, 940
Pfister, R. L. 930, 940
Pfrommer, C. V. 940, 120
Phares, D. 930, 320
Phillips, S. G. 940, 930
Pidot, G. B. 930, 320
Piercey, J. 930, 610
Pines, D. 930, 320
Pinto, J. V. 940, 030
Piore, N. K. 910, 930
Pittman, R. H. 940, 630
Pitts, A. M. 910, 840
Plaut, T. R. 940, 930
Pokrass, W. R. 930, 810
Polenske, K. R. 940, 210
Pollakowski, H. O. 930, 320
Potzin, P. E. 940, 210
Poole, R. W. 940, 820
Posatko, R. C. 900, 320
Potter, H. C. 920, 310
Pranzo, J. L. 940, 720
Prestecos, P. 940, 930
Prehn, E. C. 920, 930
Price, D. N. 910, 000
Primus, W. E. 910, 820
Prunello, W. J. 920, 630
Puffer, F. W. 940, 210
Puryear, D. L. 930, 320
Quigley, J. M. 930, 200
Rabianski, J. S. 930, 940
Rachlis, M. 930, 310
Radov, K. B. 930, 120
Rasmussen, D. W. 930, 010
Reagan, S. C. 930, 940
Redman, B. J. 920, 610
Reeb, D. J. 930, 320
Reed, E. 910, 610
Reid, C. E. 930, 320
Reid, M. G. 900, 920
Reid, R. T. 930, 320
Reid, W. E., Jr 940, 220
Reifel, J. W. 930, 110
Reinhardt, U. E. 910, 810
Reischauer, R. D. 930, 320
Rejda, G. E. 910, 500
Remch, P. M. 930, 320
Renaud, B. M. 930, 120
Reschovsky, A. 930, 320
Revzan, L. H. 940, 320
Rice, D. P. 910, 920
Richter, C. E. 940, 210
Riefler, R. F. 940, 930
Rinaldo, D. W. 910, 110
Rinehart, J. R. 940, 020
Ring, D. W. 930, 320
Rishel, H. L. 930, 210
Robertson, R. L. 910, 820
Rock, S. M. 930, 610
Rohrlich, G. F. 910, 030
Roistacher, E. A. 930
Romanos, M. C. 930, 110
Romans, J. T. 910, 940
Rosen, K. T. 930, 130
Ross, J. L. 910, 820
Rosser, J. B. 900, 000
Rosalter, L. F. 910, 320
Rothenberg, J. 930, 320
Roy, J. 940, 300
Rubin, B. M. 940, 210
Rubin, J. I. 910, 320
Rubin, M. M. 930, 320
Rubin, R. M. 930, 940
Ruchlin, H. S. 910, 040
Rucker, T. D. 910, 610
Ruster, F. H. 900, 010
Rufener, B. L. 910, 310
Rufolo, A. M. 930, 320
Rupp, A. 910, 830
Russell, K. P. 940, 930
Russell, L. B. 910, 840
Rutledge, G. L. 930, 720
Saks, D. H. 900, 800
Salins, P. D. 930, 940
Salkever, D. S. 900, 800
Salmon, R. J. 920, 930
Scanlon, W. J. 910, 320
Schafer, R. 930, 210
Schaffer, R. L. 930, 220
Schechter, H. B. 930, 310
Schelling, T. C. 900, 600
Schenker, D. 920, 220
Schlenker, R. E. 910, 610
Schmashl, W. 910, 320
Schmenner, R. W. 930, 630
Schnorbus, R. H. 940, 820
Schnyder, S. 910, 940
Schoenbaeck, W. 910, 850
Scholl, J. D. 920, 930
Scholl, K. K. 920, 010
Schouten, E. S. 910, 610
Schreiber, A. F. 930, 320
Schulenburg, J. M. 910, 410
Schuler, R. E. 930, 610
Schulman, R. 930, 920
Schulz, J. H. 910, 840
Schwab, R. M. 930, 320
Schweitzer, T. T. 920, 210
Sclar, E. D. 930, 940
Seagrave, C. E. 910, 820
Segal, D. 930, 940
Segelhorst, E. W. 930, 320
Seidenstat, P. 930, 810
Seidman, R. L. 900, 020
Seko, M. 930, 320
Seninger, S. F. 940, 930
Senn, L. 940, 630
Soo, F. 940, 050
Sepanik, R. J. 900, 200
Seskin, E. P. 930, 210
Setter, G. L. 910, 820
Settle, R. F. 910, 820
Seymour, D. R. 940, 130
Shapiro, P. 930, 020
Shaw, P. H. 940, 720
Shear, W. B. 930, 320
Sherrill, K. T. 940, 630
Shifron, G. 910, 820
Shih, K. C. 930, 220
Shim, U. 940
Shoup, D. C. 930, 320
Siegel, J. 920, 200
Siegmann, A. E. 910, 000
Silberman, J. 940, 310
Silvers, A. 910, 010
Simms, M. C. 930, 320
Simpson, W. B. 910, 610
Sindelar, J. L. 900, 800
Singell, L. 930, 850
Siskind, D. I. 930, 630
Skinner, L. E. 930, 210
Skogh, G. 920, 610
Skutt, G. 940, 110
Slavin, S. L. 930, 610
Slepian, A. P. 930, 940
Small, K. A. 930, 320
Smeeding, T. M. 910, 320
Smigel, S. E. 930, 110
Smith, B. A. 930, 320
Smith, B. A. 930, 320
Smith, H. C. 920, 820
Smith, P. R. 940, 610
Smith, S. 930, 940
Smith, T. 920, 610
Smith, V. E. 920, 210
Smolensky, E. 910, 930
Snellings, E. C. 910, 610
Snyder, T. P. 930, 320
Sobaski, W. J. 910, 610
Socher, C. F. 940, 210
Sophoulis, C. M. 930, 030
Southwick, L., Jr 900, 610
Spengler, A. W. 930, 320
Spengler, E. H. 930, 320
Stabler, J. C. 940, 610
Stamos, S. C. 900, 120
Stanbeck, T. M., Jr 930, 130
Stanley, J. K. 910, 940
Stano, M. 910, 320
Stapleford, J. E. 930, 320
Starr, E. 910, 900
Steele, M. 930, 220
Stelker, G. D. 940, 630
Stein, K. F. 920, 930
Stephenson, J. B. 920, 620
Stern, L. H. 940, 810
Stevens, B. H. 940, 930
Stevens, B. J. 930, 210
Stevens, J. G. 920
Stevens, R. D. 910, 710
Stewart, G. J. 930, 320
Stillman, R. J. 920, 520
Stimson, D. H. 910, 510
Stine, W. F. 930, 320
Stocks, A. H. 930, 320
Stover, M. E. 930, 210
Stowe, P. S. 910, 000
Strader, M. H. 930, 320
Straszheim, M. R. 930, 210
Struyk, R. J. 930, 940
Stuart, B. 910, 320
Stucker, J. P. 930, 610
Stull, W. J. 930, 210
Sullivan, D. H. 910, 320
Summers, A. A. 930, 060
Suntum, U. V. 940, 610
Sutet, B. P. 910, 810
Swagler, R. M. 920, 110
Sweet, M. L. 940, 930
Swenson, N. P. 940, 720
Tandy, W. L. 910
Tannian, F. X. 930, 900
Taylor, A. K. 910, 320
Teitz, M. B. 940, 930
Terny, G. M. 910, 320
Thompson, G. R. 940, 320
Thompson, L. C. 940, 610
Thompson, W. R. 930, 940
Thomson, J. W. 930, 010
Thrall, G. I. 930, 730
Till, T. E. 940, 110
Toda, M. 920
Todd, J. E. 910, 820
Tolpin, H. G. 910, 210
Treuner, P. H. 940, 100
Treyz, G. I. 940, 130
Troyer, M. D. 900, 510
Tuck, B. H. 940, 100
Tucker, T. L. 940, 720
Turek, J. H. 930, 940
Turnbull, J. G. 900, 800
Turner, L. A. 910, 840
Tussing, A. D. 910, 320
Ullmann, S. G. 910, 610
Umo, J. U. 930, 120
Unger, I. J. 940, 720
Uno, K. 940, 850
Updike, H. H. 930, 320
Uri, N. D. 940, 210
Vahaly, J. 930, 210
Van Alstyne, C. 900, 000
Van Beusekom, J. M. 910, 410
Vandermeulen, A. 930, 940
Van de Water, P. N. 910, 320
Van Gieson, R. A. 930, 320
Van-Praag, B. M. S. 910, 920
Vatter, E. L. 910, 920
Vaughan, R. J. 930, 720
Vazquez, H. I. 930, 120
Veatch, J. F. 900, 600
Veazie, C. E. 940, 220
Velasco, J. A. 930, 940
Verway, D. I. 940, 820

Vignola, M. L. 900, 320
Villegas, D. J. 920, 930
Villota-Villota, F. D. 910, 100
Voorhies, M. W. 910, 930
Vorst, J. I. 910, 210
Votey, H. L. 910, 840
Wachter, S. M. 930, 130
Walden, M. L. 920, 930
Walentik, D. S. 910, 800
Wallerstein, L. B. 930, 700
Walsh, J. P. 910, 940
Walzer, N. C. 930, 940
Warke, T. 930, 320
Warlick, J. L. 910, 820
Warne, C. 920, 040
Warner, J. S. 940, 800
Warner, K. E. 910, 620
Warner, L. 940, 730
Wassall, G. H. 930, 320
Wattel, H. L. 920, 610
Watts, C. A. 910, 610
Waymire, W. J. 940, 930
Wehrle, L. S. 910, 020
Weicher, J. C. 930, 320
Weimer, A. M. 930, 300
Weinberg, D. H. 910, 320
Weiserbs, D. R. G. 920, 210
Weitzman, P. 930, A00
Welch, W. P. 910, 720
Weld, E. A., Jr 930, 840
Wells, J. D. 940, 630
Wendt, P. F. 900, 940
Werner, H. D. 930, 830
Wessman, S. E. 930, 610
West, R. W. 910, 810
Wheaton, W. C. 930, 940
Wheeler, J. R. C. 910, 210
White, J. R. 930, 320
White, R. D. 930, 320
White, S. B. 930, 820
Wickman, K. P. 940, 930
Wienk, R. E. 930, 320
Wilensky, G. R. 910, 320
Willems, J. S. 910, 600
Williams, R. C. 930, 320
Williams, R. G. 940, 130
Williamson, H. F. 930, 940
Williamson, R. B. 940, 440
Willing, P. R. 940, 310
Wills, J. M. 910, 720
Wilson, A. A. 900, 440
Wilson, D. B. 910
Wilson, L. S. 900, 000
Winakor, T. G. 920, 000
Winger, A. R. 900, 500
Winnick, L. 930, 220
Witte, A. D. 930, 940
Wohlfarth, T. A. 930, 850
Wolf, D. A. 910, 840
Wood, J. C. 910, 810
Wood, K. S. 940, 930
Woodward, R. S. 913, 520
Wooldridge, J. 910, 810
Worcby, P. 940, 840
Wright, V. B. 930, 820
Wulf, J. 940, 800
Yap, L. Y. L. 930, 110
Yeager, F. S. 930, 320
Yeager, J. F. 930, 020
Yezer, A. M. 930, 940
Yinger, J. M. 930, 320
Yitzhaki, S. 910, 020
Young, J. J. 910, 920
Zaretsky, H. W. 910, 220
Zavattero, D. A. 930, 210
Zech, C. E. 930, 320
Ziegler, J. A. 940, 320
Zimmerman, M. K. 900, 220
Zimmermann, L. K. 920
Zisler, R. C. 930, 520
Zook, C. 900, 210
Zorn, P. M. 930, 610
Zubkoff, M. 910, 810
Zuckerman, A. M. 910, 930

A00 RELATED DISCIPLINES

Allan, P. A00, 210
Aranson, P. H. A00, 610
Baker, G. R. A00, 900
Balderston, J. B. A00, 210
Barcon, J. A00, 210
Barnes, D. W. A00, 610
Beveridge, A. A. A00, 120
Blake, W. H. A00
Branchini, F. A00, 080
Breyer, S. G. A00, 000
Brown, M. C. A00, 320
Brundy, J. M. A00, 310
Chu, D. S. C. A00, 400
Cole, R. C. A00
Collins, M. M. A00, 010
Cooter, R. D. A00, 320
Coulter, E. J. A00, 000
David, P. T. A00, 100
Dequae, P. R. A. A00
Desai, S. A00, 810
Fehm, K. A00, 020
Figura, R. S. A00, 930
Freund, D. A. A00, 000
Garber, A. M. A00, 850
Henning, W. L. A00
Kaufman, R. M. A00, 520
Leach, B. J. A00
Louie, R. A00, 120
Luhrmann, G. W. A00
MacRae, D., Jr A00
Morgan, M. F. A00
Moulton, D. A. A00
Ockey, V. A. A00, 210
O'Hara, N. E. A00, 320
Palmer, R. E. A00
Payne, W. S. A00, 720
Pinderski, J. W., Jr A00
Reiss, J. B. A00, 910
Remson, A. C., Jr A00
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CALIF. STATE U. AT LONG BEACH
Long Beach, CA

Atherton, W. N.
Dvorak, E. J.
Farrell, M. J.
Glezakos, C.
Hanson, R. X.
Ishimine, T.
Magaddino, J. P.
Marchand, J. R.
Meyer, D. B.
Rooney, R. F.
Segelhorst, E. W.
Skov, I. L.
Spiller, R.
Whipple, C. L.

CALIF. STATE U. AT LOS ANGELES
Los Angeles, CA

Garston, N. H.
Graham, W. R.
Hammack, J.
Ho, D. S.
Hsia, k. T.
Jensen, G.
Moore, D. A.
Mu, P. T.
Mullen, J.
Roseman, M. R.
Schnitzel, P.
Shunk, E. S.
Simpson, W. B.
Stephens, E. O.
Tomaske, J. A.
Yeager, J. F.

CALIF. STATE U. AT NORTHRIDGE
Northridge, CA

Barkume, A. J.
Blake, D. R.
Evans, K. D.
Gifford, A., Jr
Ham, C. L.
Jennings, W. P.
Krol, R.
Lawless, M. W.
Lupul, M. E.
Pedrotti, B. J.
Roberts, W. W.
Saft, L.
Spiro, H. T.
Templer, R. L.

CALIF. STATE U. AT SACRAMENTO
Sacramento, CA

Gutowsky, A. R.
Hager, P. G., III
Kerby, W. C.
Mogull, R. G.
Polkinghorn, B. H.
Renlett, J. G.
Tool, M. R.
Yamanaka, T.
Yang, Y. Y.

CALVIN COLL.
Grand Rapids, MI

Dodge, J. W.
Dykema, E. R.
Ebels, D. M.
Monsma, G. N.
Tiemstra, J. P.

CANISIUS COLL.
Buffalo, NY

Duchan, A. I.
Falkowski, D. C.
Murphy, J. S.
Palumbo, G. M.
Pfaff, P.
Schneider, K. B.
Wall, R. A.
Wilson, F. S.

CANTONSVILLE COMMUNITY COLL.
Baltimore, MD

Guelzo, C. M.

CAPITAL U.
Columbus, OH

Hansen, J. M.
Odegaard, T. A.

CARDINAL STRITCH COLL.
Milwaukee, WI

Peter, J.
Smith, D. K.

CARLETON COLL.
Northfield, MN

Adams, J. L.
Brown, K. D.
Lamson, G. H.
Paas, M. W.
Strand, S. H.
Will, R. E.

CARLETON U.
Ottawa, ON

Bernstein, J. I.
Choudhri, E. U.
Ferris, S.
Geehan, R. R.
Hettich, W.
Maslove, A. M.
Maule, C. J.
McMillan, C. H.
Park, S.
West, E. G.
Winer, S. L.

CARNEGIE-MELLON U.
Pittsburgh, PA

Avery, R. B.
Ayres, R. U.
Carey, M.
Cohen, M. A.
Crecine, J. P.
Cyert, R. M.
Davis, O. A.
Dipasquale, D. M.
Dunn, K. B.
Edward Bruce, E.
Eichenbaum, M. S.
Epple, D.
Gerber, S. G.
Gruenspecht, H. K.
Hendrickson, C.
Hodrick, R. J.
Hotz, V. J.
Kamlet, M. S.
Klepper, S. I.
Kriebel, C. H.
Kydland, F. E.
Larkey, P. D.
Leyden, D. P.
McCallum, B. T.
McGuire, T. W.
Meltzer, A. H.
Peled, D.
Penz, A. J.
Richard, S. F.
Romer, T.
Shaw, K. L.
Sibert, A. C.
Simon, H. A.
Singleton, K. J.
Spatt, C. S.
Strauss, R. P.
Timmis, G. C.
Townsend, R. M.
Williams, J. R.
Zaehringer, J.
Zelenitz, A. H.

CARTHAGE COLL.
Kenosha, WI

Van Dahm, T. E.

CASE WESTERN RESERVE U.
Cleveland, OH

Baird, R. N.
Barloon, M. J.
Beck, J. H.
Borchert, F. R.
Bowers, D. A.
Coffey, R. J.
Duro, L. E.
Erdilek, A.
Gerhart, P. F.
Gold, B.
Kelton, C. M. L.
Kratofil, B. J.
McMeekin, G. C.
Parai, A. K.
Peirce, W. S.
Quan, N. T.
Rosegger, G.
Wolf, M. A.

CATHOLIC U. OF AMER.
Washington, DC

Bolino, A. C.
Cain, L. F.
Cholewicki, V.
Fries, A. F.
Kim, U.
Murphy, J. J.
Spiegel, H. W.
Uri, N. D.
Woroniak, A.

CATHOLIC U. OF ARGENTINA
Buenos Aires, Argentina

Mantel, R. R.
Martirena-Mantel, A. M.

CATHOLIC U. OF LOUVAIN
Louvain, Belgium

Berlage, L. J. J.
de Bondt, R. R.
Deville, P. R.
Dirk, P.
Lowenthal, P.
Marchand-Bieswal, M.
Philips, L.
Steinherr, A.
Tulkens, H. G.
Watteyne, A. L.
Weiserbs, D. R. G.

CATHOLIC U. OF PORTUGAL
Lisbon, Portugal

Rapaz, V. J.

CATHOLIC U. OF RIO DE JANEIRO
Rio de Janeiro, Brazil

Carneiro-Netto, D.
Lopes, F. L.

CATHOLIC U. OF THE SACRED HEART
Milan, Italy

Dell Aringa, C.
Graziola, G.

CATHOLIC U. OF TILBURG
Tilburg, The Netherlands

Dunnewijk, T. J. A.

CATHOLIC U. OF VENEZUELA
Milan, Venezuela

Chen, C.

CENTRAL COLL.
Pella, IA

Glendening, R. N.
Maurer, R. J.

CENTRAL CONN. STATE COLL.
New Britain, CT

Kim, k. H.
Leahy, M. J.
Rippey, R. S.
Stergianopoulos, P. G.

CENTRAL FLA. COMMUNITY COLL
Ocala, FL

Miller, H. L.

CENTRAL MICH. U.
Mt. Pleasant, MI

Bathish, N. A.
Croll, R. F.
Hunter, W. J.
Mathis, P. C.
Natke, P. A.
Peterson, T. C.
Rankin, C. A.
Reynolds, R. R.
Van Der Ploeg, S. S.
Zimmer, B. G.
Zuberi, H. A.

CENTRAL MO. STATE U.
Warrensburg, MO

Adams, E. T.
Brock, B. A.
Engelmann, P. H.
Wikey, H. L.

CENTRAL PIEDMONT COMMUNITY COLL.
Charlotte, NC

Ward, R. C.

CENTRAL STATE U.
Edmond, OK

Hildred, W. M.
Tandy, W. L.
Wert, F. S.

CENTRAL U. OF VENEZUELA
Caracas, Venezuela

Barcon, J.
Carrillo-Batalla, T. E.

CENTRAL VA. COMMUNITY COLL.
Lynchburg, VA

Reynolds, W. M.

CENTRAL WASH. U.
Ellensburg, WA

Franz, W. W.
Spall, H. M.

CENTRAL WESLEYAN COLL.
Central, SC

Virkler, J. S.

CENTRE COLL. OF KY.
Danville, KY

Bramwell, W. K.
Campbell, C. W.

CESA
Jouy-en-Josas, France

Crouhy, M. G.
Crouhy-Veyrac, L. L.
Dumas, B.
Laurent, G.
Solnik, B. H.

CHALMERS U. OF TECHNOL.
Gothenburg, Sweden

Islam, S.

CHAMPLAIN COLL.
St. Lambert, PQ

Sharpe, A.

CHAPMAN COLL.
Orange, CA

Abbondante, P. J.
Booth, D. R.
Doti, J. L.
Kitchen, J. E.
Pierson Doti, L. M.
Reclam, M.

CHATHAM COLL.
Pittsburgh, PA

Townsend, R. G.

CHESTNUT HILL COLL.
Philadelphia, PA

Deans, J. S.

CHICAGO STATE U.
Chicago, IL

Kang, M. H.
Moreno, J. L.

CHINESE U. OF HONG KONG
Shatin, Hong Kong

Ho, Y.
Hsueh, T.
Liu, P. W.
Mok, V.
Nyaw, M.
Tuan, C.
Tzon-Biau, L.

CHONNAM NAT. U.
Kwang-Ju, South Korea

Lee, J.
Park, K.

CHRISTIAN ALBRECHTS U.
Kiel, West Germany

Hagemann, H.

CHRISTOPHER NEWPORT COLL.
Newport News, VA

Maniyar, V. P.

CHULALONGKORN U.
Bangkok, Thailand

Ekahitanonda, S.

CITRUS COLL.
Azusa, CA

Schreiber, W. L.

CITY COLL. OF CUNY
New York, NY

Galatin, M.
Greenwald, W. I.
Klebaner, B. J.
Marty, A. L.
Reubens, E. P.
Silver, M.

CITY COLL. OF SAN FRANCISCO
San Francisco, CA

Bardaro, J.
Theige, G. L.

CITY U. OF LONDON
London, England

Gemmill, G. T.

CLAREMONT GRAD. SCH.
Claremont, CA

Bradford, E. B.
Hinshaw, R.
Sharp, P. A.
Vandermeulen, D. C.
Warga, A. D.
Willett, T. D.

CLAREMONT MEN'S COLL.
Claremont, CA

Berson, D. W.
Eckert, R. D.
Eyrich, G. I.
Feigenbaum, S. K.
Hollerman, L.
Maciariello, J. A.
McClelland, H. F.
Meigs, A. J.
Stubblebine, W. C.
Sweeney, R. J.
Wright, C.

CLARION STATE COLL.
Clarion, PA

Balough, R. S.
Dennis, E.
Stine, W. F.
Vernon, T. T.
Wichmann, A. A.
Yang, C. W.

CLARK COLL.
Atlanta, GA

Jones, B. A. P.

CLARK COUNTY COMMUNITY COLL.
North Las Vegas, NV

Searles, E. W.

CLARKSON COLL. OF TECHNOL.
Potsdam, NY

Atesoglu, H. S.
Breece, J. H.
Congelton, R. D.
Dong, T. H.
Forbush, D. R.
Manz, F. C.
Mullen, J. K.

CLARK U.
Worcester, MA

Anderson, P. M.
Hsu, R. C.
Hughes-Cromwick, E.
Major, D. C.
Naumes, M. J.
Nicholson, H. W.
Ott, A. F.
Puffer, F. W.
Simpson, A. C.
Tannery, F. J.
Van Tassel, R. C.
Weinrobe, M. D.
Ziogas, C.

CLEMSON U.
Clemson, SC

Amacher, R. C.
Blair, D. W.
Bowles, D. C.
Cottle, R. L.
Elliott, R. D.
Hemmig, M. D.
Henry, M. S.
Hite, J. C.
Macaulay, H. H.
Maxwell, W. D.
Prinzinger, J. M.
Shannon, R. D.
Uhimchuk, G. A.
Wimer, N. K.
Yandle, B.

CLEVELAND STATE U.
Cleveland, OH

Bell, E. B.
Bodenhorn, D.
Domonkos, J. A.
Jancura, E. G.
Marcus, R. D.
Martin, L. W.
Mathur, V. K.
Rosen, H. S.
Sharma, J. L.
Stein, S. H.
Stewart, D. O.
Taub, A. J.
Warne, C.
Wald, E. A. Jr

CLINCH VALLEY COLL. OF U. OF VA.
Wise, VA

Yun, P. S.

C.N. COLL.
Tamil Nadu, India

Gnanadoss, B.

COE COLL.
Cedar Rapids, IA

Spellman, W. E.
Vaitheswaran, R.

COLBY COLL.
Waterville, ME

Christainsen, G. B.
Christiansen, R. E.
Gemery, H. A.
Hogendorn, J. S.
McCormick, K.
Meehan, J. W.
Peyson, H.
Tietenberg, T. H.
Zukowski, W. H.

COLGATE U.
Hamilton, NY

Freedman, R.
Halcrow, R. B.
Honkalehto, O.
Hou, C.
Waldman, D. E.

COLL. OF DUPAGE
Glen Ellyn, IL

Anyetei, S.
Duda, P. A.
Stavy, M.

COLL. OF FRANCE
Paris, France

Perroux, F.

COLL. OF IDAHO
Caldwell, ID

Bollinger, W. L.
Brock, L. V.

COLL. OF INDIA
Hyderabad, India

Pachauri, R. K.

COLL. OF LAKE COUNTY
Grayslake, IL

Wernke, D. W.

COLL. OF MEDICINE & DENTISTRY OF N.J.
Newark, NJ

Lewit, E. M.
Smith, N. S.

THE COLL. OF MEXICO
Mexico, Mexico

Lustig, N. C.
Serra-Puche, J.

COLL. OF NOTRE DAME
Belmont, CA

Senford, D. Z.

COLL. OF ST. CATHERINE
St. Paul, MN

Sher, G.

COLL. OF ST. MARY
Omaha, NE

McDermott, R. M.

COLL. OF ST. THOMAS
St. Paul, MN

Fischer, M. L.
Fitzharris, J. C.
Gray, C. M.
Hadjiyanis, D. P.
Jones, D. D.
Kreitzer, J. L.
Porter, D. A.
Selim, M. A.
Walsh, W.

COLL. OF STATEN ISLAND OF CUNY
Staten Island, NY

Bressler, B.
Carey, R.
Petratos, V.

COLL. OF THE DESERT
Palm Desert, CA

McKell, M. S.

COLL. OF THE HOLY CROSS
Worcester, MA

Augustyniak, C. M.
Carter, J. R.
Cross, S. M.
Dimasi, J. A.
Fahey, J. R.
Judge, J. J.
Larson, D. A.
O'Connell, J. F.
Petrella, F.
Sanchez, N.
Schap, D. J.

COLL. OF THE MIDWEST
Chicago, IL

Baron, H.

COLL. OF THE V.I.
St. Thomas, VI

Jones-Hendrickson, S. B.

COLL. OF WILLIAM & MARY
Williamsburg, VA

Archibald, R. B.
Baker, S. H.
Barry, R. A.
Finifter, D. H.
Garrett, M. A.
Harris, F. H. D.
Hausman, W. J.
Marsh, C. F.
Matthews, J. R.
Moody, C. E.
Park, C.
Parkany, J.
Quittmeyer, C. L.
Reid, W. J.
Robeson, F. E.
Schaefer, E. J.
Schifrin, L. G.
Traywick, L. E.

COLL. OF WOOSTER
Wooster, OH

Burnell, B. S.
Burnell, J. D.
Galster, G. C.
Jenny, H. H.
Reimer, R. D.
Sell, J. W.

COLO. COLL.
Colorado Springs, CO

Griffiths, L. C.
Hamilton, P. R.
Hecox, W. E.
Werner, R. O.

COLO. SCH. OF MINES
Golden, CO

Benedetti, J. C.
Cordes, J. A.
Gangwar, A.
Weber, J. C.
Welles, J. G.

COLO. STATE U.
Ft. Collins, CO

Blood, D. M.
Bowen, R. L.
Caulfield, H. P.
Fan, C.
Fan, L.
Keller, R. R.
Lybecker, D. W.
McHugh, H. F.
McKean, J. R.
Nobe, K.
Ozawa, T.
Peterson, R. D.
Revier, C. F.
Rhodes, G. F., Jr
Walsh, R. G.
Young, R. A.

COLUMBIA COLL.
Columbia, SC

Bouknight, J. G.

COLUMBIA U.
New York, NY

Adler, M.
Albrecht, J. W.
Amon, E.
Anderson, R. W.
Arzac, E. R.
Barger, H.
Bartel, A.
Batts, N. C.
Beveridge, A. A.
Braid, R. M.
Burton, J. C.
Cagan, P.
Calvo, G.
Chang, Y. M.
Chichilnisky, G.
Collery, A.
Craig, G. A.
Cunningham, T. J.
Dauhajre, A. S.
Dhrymes, P. J.
Di Tata, J. C.
Duchatelet, M.
Economides, N. S.
Edwards, F. R.
Erlich, A.
Evans, E. L.
Farley, D. E.
Florinsky, M. T.
Foley, D. K.
Freedman, M.
Gardner, R. N.
Giddy, I. H.
Gilles, C.
Ginzberg, E.
Goldman, F.
Goldstein, H. A.
Graboyes, R. F.
Grauer, F. L.
Gulley, D. A.
Harriss, C. L.
Hiestand, D. L.
Holdowsky, M. M.
Howland, J. E.
Jewett, C. A.
Johnson, W. A.
Kambhu, J. E.
Kandaswamy, S.
Kiguel, M. A.
Kroch, E. A.
Kuhn, J. W.
Lancaster, K. J.
Lawrence, C.
Leff, N. H.
Mehra, R.
Mincer, J.
Mintz, N. N.
Moock, P. R.
Nakamura, J. I.
Neuburger, H. M.
Newman, W. H.
Noah, H. J.
Noam, E. M.
Nothaft, F. E.
Obstfeld, M.
Papademos, L. D.
Phelps, E. S.
Picado Horta, C. A.
Pontecorvo, G.
Reubens, B. G.
Robock, S. H.
Rozwadowski, F. J.
Schwartz, H. A.
Sclar, E. D.
Scott, A. M.
Scott, J. H.
Selden, L.
Sexton, D. E.
Shay, R. P.
Siegmann, A. E.
Stow, A.
Vickrey, W.
Wang, N. T.
Warner, A. W.
Watts, H. W.
Wellisz, S.
Wilkinson, M.
Williams, E. W.
Wolf, C. R.
Wooton, J. F.
Zuckerman, S.
Zupnick, E.

COLUMBUS COLL.
Columbus, GA

Carbaugh, D. C.
McCollum, J. B.

COMMUNITY COLL. OF DEL. COUNTY
Media, PA

McDowell, J. H.

COMMUNITY COLL. OF PHILADELPHIA
Philadelphia, PA

Reznik, N. D.
Topiol, J.

CONCORDIA COLL. AT MOORHEAD
Moorhead, MN

Spilde, R. H.

CONCORDIA U. AT MONTREAL
Montreal, PQ

Ahmad, J.
Breslaw, J. A.
Callier, P.
Douglas, E. J.
Draimin, C. K.
Irvine, I. J.
Jackson, A. G.
Lallier, A. G.
Muller, F. G.
O'Brien, J. W.
Riener, K. D.
Shapiro, D. M.
Siggel, E. W.
Sims, W. A.
Stephanos, G.

CONCORDIA U. AT SIR GEORGE WILLIAMS CAMPUS
Montreal, PQ

Ahsan, S. M.
Bartel, H.
Corbo, V.
Ford, R.
Stelcner, M.

CONN. COLL.
New London, CT

Schoene, S. W.
Visgilio, G. R.

CONVERSE COLL.
Spartanburg, SC

Williamson, E.

COPENHAGEN SCH. OF ECONS. & BUS.
Copenhagen, Denmark

Lund, L.
Nielsen, N. C.
Stetting, L.

COPPIN STATE COLL.
Baltimore, MD

Akyeampong, K.
Alpern, M.
Pearl, L. R.

CORNELL COLL.
Mount Vernon, IA

Cell, D. C.

CORNELL U.
Ithaca, NY

Anderson, B. L.
Batista, J. C.
Bazzoli, G. J.
Biesdorf, H. B.
Blandford, D.
Boisvert, R. N.
Briggs, V. M.
Bryant, W. K.
Burton, J. F., Jr
Caldwell, S. B.
Cesario, F. J.
Chapman, D.
Clemhout, S.
Cole, K. L.
Conrad, J. M.
Curtis, R. T.
Czamanski, S.
Douthitt, R. A.
Easley, D.
Eastaugh, S. R.
Ebrill, L. P.
Ehrenberg, R. G.
Falkson, L. M.
Fields, G. S.
Frank, R. H.
Gerner, J. E.
Gerner, J. L.
Gould, B. W.
Greene, W. H.
Grinols, E. L., III
Hall, B. F.
Hay, G. A.
Hornig, E. C.
Hutchens, R. M.
Hutchins, J. G. B.
Isard, W.
Jarrow, R. A.
Johnson, M. S.
Jones, B. G.
Kahn, A. E.
Kalter, R. J.
Kiefer, N. M.
Ladue, E. L.
Lau, M.
Lee, M. J.
Lind, R. C.
Lipsky, D. B.
Lyons, T. P.
Marston, S. T.
Masson, R. T.
Maynes, E. S.
McClelland, P. D.
Mitchell, O. S.
Morse, C.
Mount, T. D.
Muse, B.
Novakovic, A. M.
Oldfield, G. S.
Oum, B.
Possen, U. M.
Reppy, J. V.
Rock, C. P.
Ruchlin, H. S.
Rupp, A.
Saltzman, S.
Schuler, R. E.
Schwartz, N. E.
Smidt, S.
Smiley, R.
Staller, G. J.
Svejnar, J.
Tauer, L. W.
Terrell, K. D.
Thaler, R. H.
Thorbecke, E.
Tomek, W. G.
Tsiang, S. C.
Wilson, N. H.
Young, R.
Zick, C. D.

COUNTY COLL. OF MORRIS
Randolph Township, NJ

West, T.

CREIGHTON U.
Omaha, NE

Nitsch, T. O.
Robertson, L. S.

CULVER-STOCKTON COLL.
Canton, MO

Kenney, T. W.

CUNY GRAD. SCH. & U. CTR.
New York, NY

Bonitsis, T. H.
Bookbinder, A. I. A.
Edwards, L. N.
Grossman, M.
Lally, J. K.
Maher, J. J., Jr
Mourgos, S. L.
Muller, C. F.
Roy, J.
Sauerecker, E.
Yamada, T.

CURRY COLL.
Milton, MA

Eckert, J. K.
Wertheimer, R. G.

CUYAHOGA COMMUNITY COLL.
Cleveland, OH

Coleman, J. S.
Johnson, W. H.
Needham, J. E.

CUYO U.
Mendoza, Argentina

Verstraete, J.

CYPRESS COLL.
Cypress, CA

Phillips, J. A.

DAKOTA WESLEYAN U.
Mitchell, SD

Mitchell, D. B.

DALHOUSIE U.
Halifax, NS

Comeau, R. L.
Cornwall, J.
Cross, M. L.
Harvey, A. S.
Huber, P. B.
Marfels, C. T.
Osberg, L. S.
Roberts, G. S.
Rugman, A. M.
Wood, K. S.

DANKOOK U.
Seoul, South Korea

Kim, Y. K.
Park, D. U.

DARMSTADT INSTITUTE OF TECHNOL.
Darmstadt, West Germany

Schlicht, E.

DARTMOUTH COLL.
Hanover, NH

Baldwin, W. L.
Barthold, T. A.
Bower, R. S.
Campbell, C. D.
Clement, M. O.
Dougan, W. R.
Dunlop, D. W.
Fischel, W. A.
Gustman, A. L.
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Kenyon, D. A.
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Duffy, J. A., Jr
Flubacher, J. F.
George, D. L.
Gerusoon, R. T.
Grady, J. S.
Kane, J. A.
Rhoda, K. L.
Williams, M. W.

LA TROBE U.
Bundoora, Australia

Davidson, F. G.
Dumsday, R. G.
Freebairn, J. W.
Goddard, E. W.
Langley, P. C.
Mahoney, D. M.
Quilkey, J. J.
Sgro, P. M.

LAURENTIAN U.
Sudbury, ON

Barnett, E. V.
Eastman, B. D.
Sakellariou, D. M.
Ton-That, T.
Willauer, E. T.

LAWRENCE U.
Appleton, WI

Finkler, M. D.
Larocque, J. N.

LEBANON VALLEY COLL.
Annville, PA

Foeller, W. H.
Tom, C. F. J.

LEHIGH U.
Bethlehem, PA

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Aronson, J. R.
Belabkins, N. W.
Cohen, A.
Garb, G.
Hilley, J.
Hyclak, T. J.
Kantor, L. G.
King, A. E.
Largay, J. A.
McNamara, J. R.
Moran, R. A.
Munley, V. G.
Schwartz, E.
Thornton, R. J.

LEIDEN STATE U.
Leiden, The Netherlands

Brand, W.
Van-Praag, B. M. S.
Wessels, R. E.

LE MOYNE COLL.
Syracuse, NY

Conger, D. J.
Eron, J. J.
Johnson, J. C.

LEMOYNE-OWEN COLL.
Memphis, TN

Wojtun, B. S.

LENOIR RHYNE COLL.
Hickory, NC

Mauney, W. M.

LEWIS & CLARK COLL.
Portland, OR

Mattersdorff, G. H.
Mulee, A. M.
O'Bannon, N. D.
Ray, G.

LIMESTONE COLL.
Gaffney, SC

Hopkins, R. J.

LIMOGES U.
Limoges, France

Archer, R.

LINFIELD COLL.
McMinnville, OR

Blodgett, F. C.

LOCK HAVEN STATE COLL.
Lock Haven, PA

Wion, D. A.

LOMA LINDA U.
Loma Linda, CA

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LONDON BUS. SCH.
London, England

Bell, R. J.
Freris, A. F.
Simmonds, K.

LONDON SCH. OF ECONS.
London, England

Alogoskoufis, G. S.
Atkinson, A. B.
Coughlan, J. A.
Desai, M. J.
Dougherty, C. R. S.
Edison, H. J.
Foldes, L. P.
Forouten, F.
Grimm, K. D.
Huff, W. G.
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Klappholz, K.
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Repullo Labrador, R.
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Wills, H. R.

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Brooklyn, NY

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Levine, J. M.
Levine, R.
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Wolitzer, P.

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Khasigian, A.

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Harju, M. W.

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Ruston, LA

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Mt. Clemens, MI

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Shingleton, W.
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Huntington, WV

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Sellekaerts, W.

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Tarrytown, NY

Ferrari, R. J.

MARYMOUNT COLL. OF VA.
Arlington, VA

Marshall, F. L. L.

MARY WASHINGTON COLL.
Fredericksburg, VA

Rycroft, R. S.

MARYWOOD COLL.
Apalachin, NY

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Shapiro, M. D.
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Wheaton, W. C.
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Winston, C. M.
Wood, D. O.
Zannetos, Z. S.
Zimmerman, M. B.

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Matsuyama, Japan

Takenaka, T.

MCGILL U.
Montreal, PQ

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Beach, E. F.
Brecher, I.
Brenner, R.
Cairns, R. D.
Chateau, J. D.
Davenport, P.
Deutsch, A.
Do, T. Q.
Durosier, A.
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Gregoire, P.
Handa, J. C.
Kefalas, P.
Rorke, C. H.
Rowley, J. C. R.
Soderstrom, L. A.
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Watson, S. C.

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Chan, L.
Dooley, M. D.
Feeny, D.
George, P. J.
Harrison, A. J.
Johnson, J. A.
Kirman, W.
Kubursi, A. A.
Kwan, C. C. Y.
McCabe, P. J.
Mestelman, S.
Muller, R. A.
Papageorgiou, G. J.
Poon, N.
Samdal, A. G.
Schlatter, W. J.
Serletis, A.
Sowa, E. N. K.
Spencer, B. G.
Thompson, R. W.
Welland, J. D.
Williams, J. R.

MCMURRY COLL.
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Flores, M.

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Whitehead, P. J.

MEDGAR EVERS COLL. OF CUNY
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MEIJI GAKUIN U.
Tokyo, Japan

Kawashima, Y.
Kita, N.

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St. John's, NF

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Roy, P. N.
Schrank, W. E.

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Memphis, TN

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Carroll, T. M.
Chang, C. F.
Chisholm, R. K.
Chrysomilides, G. S.
Ciscel, D. H.
Daniel, C., III
Dean, R. D.
Depperschmidt, T. O.
Evans, R. D.
Gootzeit, M. J.
Pyun, C. S.
Rakowski, J. P.
Scruggs, L. S.
Tuckman, B. H.
Uzoaru, B. O.
Wells, D. R.

MERCER U.
Macon, GA

Andrews, C. H.
Barber, G. R., Jr
Clotfelter, C. P.
Mounts, W. S.

MERCY COLL.
Dobbs Ferry, NY

Grunewald, D.

MERRIMACK COLL.
North Andover, MA

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MESA COMMUNITY COLL.
Mesa, AZ

Pfefferbaum, R.

METROPOLITAN STATE COLL.
Denver, CO

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Cell, S. T.
Lyell, E. H.

METROPOLITAN STATE U.
Minneapolis, MN

Wolfe, F. E.

MIAMI-DADE COMMUNITY COLL.
Miami, FL

Reque, R. B.

MIAMI U. AT OXFORD
Oxford, OH

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Brown, D. G.
Cymrot, D. J.
Dunlevy, J. A.
Erekson, O. H.
Ferguson, J. D.
Fields, T. W.
Goodell, G. S.
Gustafson, E. F.
Hart, W. R.
Hutchinson, W. K.
Kehr, J. B.
Lunn, J. E.
Miller, G. M.
Moser, D. A.
Moser, J. W.
Noble, N. R.
Pagano, M. A.
Schwartz, L. B.
Schwartz, S.
Seiver, D. A.
Snider, D. A.
Sullivan, D. H.
Taylor, T. A.

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East Lansing, MI

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Ahmed, E.
Allen, B. T.
Allen-Schult, E.
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Block, R. N.
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Booth, J. H.
Boyer, K. D.
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Carlin, E. A.
Cervin, R.
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Chappelle, D. E.
Chase-Lansdale, W. C.
Chung, K.
Eicher, C. K.
Fienup, D. F.
Fisher, R. C.
Gleason, S. E.
Goddeeris, J. H.
Hamermesh, D. S.
Hardin, E.
Hazard, J. L.
Henderson, J. P.
Holland, A. S.
Hollander, S. C.
Hunter, J. M.
Johannes, J. M.
Jordan, J. L.
Kohlhase, J. E.
Koo, A. Y. C.
Kreinin, M. E.
Ladenson, M. L.
Lasater, D. B.
Libby, L. W.
Liedholm, C. E.
Manderscheid, L. V.
Martin, S.
Mead, D. C.
Menchik, P. L.
Miracle, G. E.
Mook, S. A.
Nasseh, A.
Obst, N. P.
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Olson, A. C.
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Rasche, R. H.
Rence, C. C.
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Saks, D. H.
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Sheehey, E. J.
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Smith, V. E.
Solo, R. A.
Stevens, R. D.
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Strauss, J.
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Teigen, L. D.
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Wein, H. H.
Whelan, W. P.

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Remington, L. J.

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Clayton, Australia

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Fels, A. H.
Gannon, C. A.
Giles, D. E.
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Nellor, D. C.
Ng, Y.
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Rice, R. C.
Snape, R. H.
Upcher, M. R.
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Melbourne, Australia

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Trainor, J. F.
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Samii, S.

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Morehead, KY

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Muenster, West Germany

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Murdoch, Australia

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MURRAY STATE U.
Murray, KY

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Tokyo, Japan

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MUSKEGON COMMUNITY COLL.
Muskegon, MI

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New Concord, OH

Thomson, H. F.

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Shim, U.

NAGOYA U.
Nagoya, Japan

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Murata, Y.
Ota, T.

NANZAN U.
Nagoya, Japan

Mori, T. S.

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Buenos Aires, Argentina

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PHOENIX COLL.
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Eller, C. A.
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Gregor, J. J. J.

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London, England

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Barcelona, Spain

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Madrid, Spain

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Brown, B. W.
Brown, J. N.
Brownstone, D.
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De Macedo, J. A. B.
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Germany, J. D.
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RYUKOKU U.
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Flagg, D. A.
Flagg, V. G.

Galloway, F. J.
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Grossbard, A.
Hambleton, J. W.
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Cain, J. P.
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King, A. T.
Rubenstein, H. L.
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Urbisaia, H. L.

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Balderston, F. E.
Balderston, J. B.
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Berck, P.
Berger, A. N.
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Brady, H. E.
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Cecchetti, S. G.
Chan, Y.
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Collado, J. C.
Collignon, F. C.
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Downes, D. H.
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Hall, H. H.
Harvey, C. E.
Hiremath, B. N.
Hotelling, H., Jr
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Jessee, D. L.
Jessee, K. E.
Kang, J.
Levin, J. E.
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Marxsen, W. B.
McCoy, D. R.
McMillin, W. D.
Nickless, P. J.
Pagoulatos, A.
Ramos, H.
Randall, A. J.
Renfro, C. G
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Bhattacharya, M.
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Greene, M. N.
Gregory, G. R.
Grimes, D. R.
Grosse, R. E.
Grosse, S. O.
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Hymans, S. H.
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Jensen, E.
Josserand, H. P.
Juster, F. T.
Kahkonen, J. S.
Kang, B. H.
Kashner, T. M.
Katona, G.
Kim, E. H.
Kmenta, J.
Kouyoumdjian, H. E.
Laitner, J.
Leabo, D. A.
Longe, P. S.
Loury, G. C.
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Makinen, M.
McCracken, P.
Mitchell, K.
Morgan, J. N.
Mueller, E.
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Roberts, D. C.
Rubinfeld, D. L.
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Schwartz, A. R.
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Shapiro, K. H.
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Simmons, G. B.
Smith, J. D.
Spivey, W. A.
Stafford, F. P.
Steiner, P. O.
Stern, R. M.
Stolper, W. F.
Teigen, R. L.
Thomas, A. R.
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Warner, K. E.
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Wright, G.

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Jesness, O. B.
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Landwehr, J. B.
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Caplan, E. H.
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Cummings, R. G.
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Gregory, P.
Hymel, M. J.
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McLain, J. J.
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McColl, G. D.
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Tonkin, R. S.
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Beron, K. J.
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Carleton, W. T.
Chong-MA, B.
Cohen, R. S.
Coulter, E. J.
Field, A. J.
Freund, D. A.
Froyen, R. T.
Gallman, R. E.
Gottfried, R. R.
Guilkey, D. K.
Harris, R. S.
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Hinson, H. T., Jr
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Keech, W. R.
Kniesner, T. J.
Larson, B. D.
Lee, M. W.
Lee, T. Y.
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Otoole, T. P.
Pfouts, R. W.
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Santomero, A. M.
Sechzer, S. L.
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Snead, K.
Solomons, D.
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Steinberg, R. S.
Summers, A. A.
Summers, R.
Taubman, P. J.
Taylor, N. L.
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Wachter, S. M.
Walter, J. E.
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Doctors, S. I.
Evans, J. H.
Frank, R. G.
Gal-or, E.
Giarratani, F.
Gruver, G. W.
Gupta, K.
Hilliard, E. P.
Hooley, R.
Husted, S. L.
Katz, A. M.
Katz, S. M.
Kenkel, J. L.
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Makhija, A. K.
Mandelker, G.
Mesa-Lago, C.
Nelson, W. G.
Nguyen, D.
Ochs, J. N.
Olson, J. E.
Perezmata, A. M.
Perlman, M.
Rhee, S. G.
Richman, R. L.
Slesinger, R. E.
Sontheimer, K. C.
Spiro, M. H.
Sussna, E.
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Arecibo, PR

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Bayamon, PR

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Mayaguez, PR

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Rio Piedras, PR

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Choudhury, P.
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Phillips, W. A.
Plowman, E. G.
Veazie, C. E.

U. OF SOUTHERN MISS.
Hattiesburg, MS

Cameron, C.
Carter, G. H.
Daniel, D. L.
Dennis, C. N.
Hamwi, I. S.

U. OF SOUTH FLA.
Tampa, FL

Beenhakker, A.
Brunhild, G.
Cooke, J. P.
Curtis, T. D.
Ford, E. J.
Grigg, V. H.
Hanni, E. A.
Hodgson, J. S.
James, H. W.
Kares, P.
Moss, R. L.
Rivard, R. J.
Rowe, J. W.
Steinike, G. C.
Stevens, D. N.
Wilson, R. M.

U. OF SOUTHWESTERN LA.
Lafayette, LA

Cornwell, D. W.
Manuel, D. P.
McLauchlan, J. M.

U. OF STELLENBOSCH
Stellenbosch, South Africa

Spies, P. H.

U. OF STIRLING
Stirling, Scotland

Brown, C. V.
Hare, P. G.
Loasby, B. J.
Shone, R.

U. OF STOCKHOLM
Stockholm, Sweden

Blomquist, N. S. M.
Bohm, P. J. G.
Frenckner, T. P.
Gottfries, C. G. N.
Grassman, S.
Lindbeck, A. C. E.
Lindskog, D. C.
Myhrman, J.
Myrdal, G.
Nilsson, B. J.
Noren, P. B. R.
Sardelis, C.
Soderstrom, H. T.
Svensson, L. E. O.
Werin, L. H. V.

U. OF STRATHCLYDE
Glasgow, Scotland

Huq, M. M.

U. OF STUTTGART
Stuttgart, West Germany

Majer, H.
Schnabl, H.
Treuner, P. H.

U. OF SUSSEX
Brighton, England

Holmes, P. M.
Wall, D.

U. OF SYDNEY
Sydney, Australia

Batterham, R. L.
Campbell, K. O.
Fisher, B. S.
Gelber, F.
Gill, F.
Groenewegen, P. D.
Jones, E.
Phipps, A. J.
Ray, N. R.
Ross, R. T.
Saunders, P. G.
Whiteman, J. L.
Yates, J. N.

U. OF TAMPA
Tampa, FL

Brust, P. J.
Davis, T. J.

U. OF TAMPERE
Tampere, Finland

Ahtiala, K. P.
Hamalainen, A.

U. OF TASMANIA
Tasmania, Australia

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Molhuysen, P. C.

U. OF TECHNOL. AT EINDHOVEN
Leonde, The Netherlands

Wemelsfelder, J.

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Chattanooga, TN

Eaves, G. G.
Peterson, W. H.
Rabin, A. A.

U. OF TENN. AT KNOXVILLE
Knoxville, TN

Boehm, T. P.
Bohm, R. A.
Bowlby, R. L.
Carroll, S. L.
Chang, H.
Clark, D. P.
Cole, W. E.
Donn, C. B.
Eastwood, D. B.
Feiwel, G. R.
Fox, W. F.
Glustoff, E.
Goolsby, W. C.
Herzog, H. W.
Jensen, H. E.
Kaserman, D. L.
Kocher, L. A.
Lau, P.
Mayo, J. W.
Murphy, K. J.
Postma, P.
Qualls, P. D.
Renner, D. L. W.
Scheiner, J. H.
Shrieves, R. E.
Thompson, H. L.
Wells, G. R.
Wickham, E. D.

U. OF TENN. AT MARTIN
Martin, TN

Figgins, B. G.

U. OF TEX. AT ARLINGTON
Arlington, TX

Carney, K.
Hayashi, P. M.
Holland, T. E.
Isakson, H. R.
McCrea, J. M.
Mullendore, W. E.
Swanson, P. E.
Tansey, M. M.
Trapani, J. M.
Tway, J. W.
Yoon, K. M.
Ziegler, L. F.

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Austin, TX

Askari, H.
Barnett, W. A.
Blair, C. P.
Boske, L. B.
Cohen, W. J.
Cooper, W. W.
Decy, D. C.
Darity, W. A.
Doenges, R. C.
Fayyad, S. K.
Geraci, V. J.
Gillette, L. G.
Gilley, O. W.
Glover, R. W.
Gordon, W. C.
Gronouski, J. A.
Grubb, W. N.
Hansen, N. M.
Holt, C. C.
Ivie, W. W.
Jacobs, E. A.
Jannuzi, F. T.
Kendrick, D. A.
Klan, M. S.
Lyon, R. M.
MacMinn, R. D.
Magee, S. P.
McDonald, S. L.
McKie, J. W.
Mettlen, R. D.
Mitchell, D. W.
Morgan, G. E.
Moridaira, S.
Olson, J. A.
Page, F. H.
Quintanilla, P. J.
Saulniers, A. H.
Smith, S. D.
Spellman, L.
Stolp, C.
Vogel, T.
Weintraub, S.
Williamson, R. B.
Witt, R. C.
Wolf, H. A.

U. OF TEX. AT DALLAS
Richardson, TX

Anderson, E. E.
Barton, M. F.
Cummings, F. J.
Dumas, L. J.
Enthoven, A. J.
Guisinger, S. E.
Ingene, C. A.
Katzman, M. T.
Lewin, P.
Reynolds, H.
Ruhter, W. E.
Waters, A. R.

U. OF TEX. AT EL PASO
El Paso, TX

Brand, M.
Brocato, J.
Brown, E. K.
Roth, T. P.
Schauer, D. A.
Smith, W. D.
Tollen, R. D.
Zook, P. D.

U. OF TEX. AT HOUSTON
Houston, TX

Lairson, D. R.
Swint, J. M.

U. OF TEX. AT ODESSA
Odessa, TX

Hodges, P. E.

U. OF TEX. AT SAN ANTONIO
San Antonio, TX

Furino, A.
Truett, D.
Truett, L. F.
Wolitz, L. B.

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Merida, Venezuela

Hocevar, J.

U. OF THE PACIFIC
Stockton, CA

Ballot, M. H.
Bryan, D. W.
Tetsch, P. A.
Turoff, S.
Wagner, W. C.

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Manila, The Philippines

Castro, A. A.

U. OF THE RYUKYUS
Naha City, Japan

Kakazu, H.

U. OF THE SOUTH
Sewanee, TN

Degen, R. A.
Goodstein, M. E.
Green, J. K.

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Suva, Fiji

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St. Augustine, Trinidad

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Henry, R. M.

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Kingston, Jamaica

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Tachi, R.
Uzawa, H.

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Toledo, OH

Biggs, R. M.
Gleason, A. H.
Kozlowski, P. J.
Lindsley, D. A.
Magura, M.
Reynolds, R. S.
Shapiro, E.
Sherman, M. D.
Taoka, G. M.
Weiss, S. J.
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Yankovic, D. J.

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Torino, Italy

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Contini, B.
Gallone, A.
Garbero, P.

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Toronto, ON

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Armstrong, J.
Berkowitz, M. K.
Berry, R. A.
Bird, R. M.
Bossons, J. D.
Brean, D. J.
Breton, A.
Bucovetsky, M. W.
Carr, J. L.
Casas, F. R.
Cohen, A. J.
Cohen, J. S.
Denny, M. G. S.
Dewees, D. N.
Dungan, D. P.
Dupre, R.
Eastman, H. C.
Farmer, R. E. A.
Floyd, J. E.
Foot, D. K.
Fuss, M. A.
Gordon, M. J.
Gunderson, M. K.
Haines, G. H.
Halpern, P. J.
Ham, J. C.
Hartle, D. G.
Hay, R. W.
Helleiner, G. K.
Hollander, S.
Hossain, I.
Howson, S. K.
Hsiao, C.
Kompas, T. F.
Krashinsky, M.
Landa, J. T.
Levenstein, J.
Mathewson, G. F.
McLennan, A. M.
Melino, A.
Meltz, N. M.
Moggridge, D. E.
Murenbeeld, M.
Nautiyal, J. C.
Newman, G.
Nguyen, T. T.
Pesando, J. E.
Peters, M.
Poapst, J. V.
Poirier, D. J.
Rawski, T. G.
Rea, K. J.
Rea, S. A., Jr
Reid, F.
Rogers, J. S.
Safarian, A. E.
Saunders, R. S.
Sawyer, J. A.
Smith, L. B.
Stager, D. A. A.
Stein, L. A.
Thornton, D. B.
Triantis, S. G.
Turnbull, S. M.
Wall, G. W.
Waters, W. R.
Westin, R. B.
Wilson, T. A.
Winder, J. W. L.
Winter, R. A.
Yatchew, A. J.

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Toulouse, France

Freixas, X.
Laffont, J.

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Trier, West Germany

Knappe, E. D.
Sadowski, D.

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Ibaraki, Japan

Asako, K.
Kanemoto, Y.
Kubo, Y.
Maruyama, Y.
Mera, K.
Odagiri, H.
Sakai, Y.
Wago, H.

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Tuebingen, West Germany

Buchholz, W.
Cansier, D.
Molsberger, J.
Scheele, E.
Schubert, R.

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Tulsa, OK

Bonham, J. M.
Gup, B. E.
Hinckley, R.
Soltow, A. R.
Steib, S. B.

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Ulm, West Germany

Famulla, R. M.

U. OF UMEA
Umea, Sweden

Gaunitz, S.
Lofgren, K. G.

U. OF UPPSALA
Uppsala, Sweden

Bergstrom, V.

U. OF UTAH
Salt Lake City, UT

Brunton, B. G.
Fakhraie, B.
Gander, J. P.
Girton, L.
Kiefer, D.
Miller, J. R.
Peckham, B. W.
Reynolds, S. E.
Robson, R. T.
Rock, J. M.
Roper, D. E.
Seninger, S. F.
Sievers, A. M.
Smeeding, T. M.
Stewart, S. S.
Sugiyama, S. O.

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Valencia, Spain

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Quesada, J.

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Venice, Italy

Canziani, A.
Giavazzi, F.
Leon, P.

U. OF VT.
Burlington, VT

Alnasrawi, A.
Bates, T.
Campagna, A. S.
Chase, R. X.
Coghlan, B. C.
Gaspari, K. C.
Gatti, J. F.
Woolf, A.

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Victoria, BC

Avio, K. L.
Bish, R. L.
Jones, J. C.
Laudadio, L.
Loken, M. K.
Pal, I. D.
Rutherford, M. H.
Schaafsma, J.
Walsh, W. D.
Walter, G. R.

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Vienna, Austria

Karsch, C.
Maerz, E.
Nowotny, E. O.
Orosel, G. O.
Raffer, K.
Schuster, W.
Tintner, H. C. G.
Weigel, W.
Winckler, G.

U. OF VA. AT CHARLOTTESVILLE
Charlottesville, VA

Beckenstein, A. R.
Breit, W. L.
Brooks, B. G.
Broome, O. W., Jr
Browning, E. K.
Burmeister, E.
Caniglia, A. S.
Crocker, K. J.
Curran, R. F., Jr
Elzinga, K. G.
Epps, M. L.
Epps, T. W.
Firestone, F. N.
Gabel, H. L.
Grayson, L. E.
Greenslade, G. S.
Hamilton, J. D.
James, J. A.
Johnson, W. R.
Kenyon, P.
Knapp, J. L.
Landry, R. S.
McKean, R. N.
Meiburg, C. O.
Michener, R. W.
Mills, D. E.
Nardinelli, C.
Olsen, E. O.
Pikrallidas, C. E.
Selden, R. T.
Sherman, R.
Sihler, W. W.
Snow, A.
Stein, H.
Stevens, J. L.
Taub, B.
Taylor, P. A.
Van Beusekom, J. M.
Vining, R.
Warren, R. S.
Wasmuth, E. H., Jr
Whitaker, J. K.
Wood, W. C.
Yeager, L. B.

U. OF WAIKATO
Hamilton, New Zealand

Baas, H. J.
Harris, S. G.
Silverstone, B. D. J.
Tressler, J. H.

U. OF WARWICK
Coventry, England

Ahmad, E.
Miller, M. H.
Renshaw, G. T.
Seade, J.
Stern, N. H.
Weller, P. A.

U. OF WASH.
Seattle, WA

Alberts, W. W.
Berzel, Y.
Bassett, L. R.
Beyers, W. B.
Bhagat, S.
Bold, F. C.
Bourque, P. J.
Brown, G.
Cavanaugh, K. L.
Cheung, S. N. S.
Conrad, D. A.
Cox, J. B.
Dambrosio, C. A.
Dubofsky, D. A.
Englander, E.
Englin, J. E.
Fabricant, R. A.
Fishback, P. V.
Frisch, D. J.
Frost, P. A.
Gilbreath, W. J. S.
Greulich, F. E.
Halvorsen, R.
Harrington, J. W., Jr
Hartman, R. C.
Hashimoto, M.
Henning, C. N.
Hess, A. C.
Heyne, P. T.
Higgs, R.
Hoffman, L. A.
Ito, S.
Jacob, N. L.
Kochin, L. A.
Koenig, E. F.
Krumme, G.
Leffler, K. B.
Lesser, J. A.
Makin, J. H.
McCaffree, K. M.
McGee, J. S.
Mendelsohn, R. O.
Monsen, R. J.
Morris, M. D.
Morrison, D. G.
Narver, J. C.
Nelson, C. R.
North, D. C.
Page, A. N.
Parks, R. W.
Peretz, P.
Plummer, M. L.
Rao, P. M.
Rice, E. M.
Robinson, D. E.
Roehl, T. W.
Saunders, L. E.
Schell, L. D.
Sheldon, G. G.
Silberberg, E.
Spratlen, T. H.
Strazicich, M. C.
Sundem, G. L.
Thomas, M. D.
Thornton, J.
Watts, C. A.
Worcester, D. A., Jr
Yarbrough, B. V.
Yarbrough, R. M.
Zerbe, R. O.

U. OF WATERLOO
Waterloo, ON

Bernhardt, I.
Brox, J. A.
Conrath, D. W.
Dufournaud, C. M.
Fletcher, L. P.
Ghosh, S. K.
Hotson, J. H.
Kardasz, S. W.
Kerton, R. R.
Kumar, R.
Needleman, L.
Thirsk, W. R.

U. OF WESTERN AUSTRALIA
Nedlands, Australia

Clements, K. W.
Frank, W. T.
Ghosh, R. N.

U. OF WESTERN ONT.
London, ON

Bhatia, K. B.
Blomquist, A. G.
Boyer, R. S.
Bucovetsky, S.
Burgess, D. F.
Chilton, J. B.
Davies, J. B.
Fox, G. C.
Fried, J. S.
Hanis, E. H.
Harley, C. K.
Horstmann, I. J.
Howitt, P. W.
Jimenez, E.
Laidler, D. E. W.
Lawson, E.
Lecraw, D. J.
Leith, J. C.
Liebowitz, S. J.
MacDonald, G. M. T.
Margolis, S. E.
Melvin, J. R.
O'Dell, S.
Palmer, J. P.
Petersen, T. H.
Robson, A. J.
Saraydar, E.
Slivinski, A. D.
Tomes, N.
Veall, M. R.
Welland, D. A.
Wintrobe, R. S.
Wonnacott, R. J.
Wrobel, M. G.

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Pensacola, FL

Dukes, J. H.
Teichert, P. C. M.

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Windsor, ON

Cowan, R. K.
Fallenbuchl, Z. M.
Fortune, J. N.
Kolinski, R. N.
Kovacs, A. E.
Mendels, R. P.
Phillips, W. G.
Rosenbaum, E.
Strick, J.
Sydor, L. P.

U. OF WINNIPEG
Winnipeg, MB

Snidal, D. J.

U. OF WIS. AT EAU CLAIRE
Eau Claire, WI

Carbaugh, R. J.
Egan, J. P.
Ellickson, D. L.
Oyen, D. B.
Pattison, R. V.
Vanegas F, M.
Wassink, D.

U. OF WIS. AT GREEN BAY
Green Bay, WI

Better, M. B.
Murray, J. M.
Troyer, M. D.

U. OF WIS. AT LA CROSSE
La Crosse, WI

Clark, B. S.
Colclough, W. G.
Daellenbach, L. A.
Lephardt, G. P.
Maris, B. A.
Sweetland, D. P.
Wehrs, W. E.

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Madison, WI

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Andrews, M. D.
Balcer, Y. M.
Baldwin, R. E.
Bergstrand, J. H.
Bilkey, W. J.
Bromley, D. W.
Buongiorno, J.
Buse, R. C.
Cain, G. G.
Caulkins, P. P.
Caves, D. W.
Chao, K.
Chapman, B. R.
Chou, J.
Christensen, L. R.
Cicchetti, C. J.
Clarke, R. N.
Clodius, R. L.
Cramer, R. H.
Culbertson, J. M.
Danziger, S. H.
David, M. H.
Dickman, A. L.
Dobson, W. D.
Dorner, P. P.
Dorsey, T. W., Jr
Garfinkel, I.
Geweke, J.
Gilless, J. K.
Goldberger, A. S.
Gumucio, D. R.
Hansen, W. L.
Harkin, D. A.
Harlan, K. M.
Haveman, R. H.
Hester, D. D.
Hirschey, M.
Holden, K. C.
Jakubson, G. H.
Johnson, D. B.
Johnson, M. B.
Kepner, J. W.
Kovenock, D.
Lachman, J. A.
Lacker, J. M.
Lampman, R. J.
Lee, D. R.
Lee, M.
Levine, S. B.
Masters, S. H.
McCulloch, R.
Menke, T. J.
Miracle, D. S.
Miracle, M. P.
Mueller, W. F.
Murden, W. C.
Nichols, D. A.
Ozanne, R. W.
Pappas, J. L.
Plesko, G. A.
Richardson, J. D.
Rossmiller, R. A.
Rothschild, M.
Sapir, A.
Senbet, L. W.
Smith, S. C.
Smolensky, E.
Somersan, A. C.
Stanley, C. E.
Stern, J. L.
Stevenson, R. E.
Talmor, E.
Thiel, S. E.
Thompson, H. E.
Tozier, D. E.
Tretheway, M. W.
Umentum, P. P.
Voos, P. B.
Weisbrod, B. A.
Weiss, L. W.
Wiedemer, J. D.
Williamson, J. G.
Wilson, C. A.
Wolfe, B. L.
Zwecher, M. J.

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Arora, S. S.
Chou, V. K.
Das, S. P.
Desalvo, J. S.
Elliott, J. W.
Fixler, D. J.
Han, S.
Heilmann, R. L.
Holahan, W.
Komijani, A.
Lee, T. H.
Lurie, M.
Mamalakis, M. J.
Niho, Y.
Perkins, G. M.
Perlman, R. W.
Pesek, B. P.
Pinsky, N. J.
Schenker, E.
Schur, L. M.
Shalit, S. S.
Shammas, C.
Sherony, K. R.
Swidler, S.
Weber, C. E.
White, S. B.

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Forgang, W.
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Loy, D. C.
Patterson, B. I.

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Kenosha, WI

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Jones, F. W.
Keehn, R. H.
Rieber, W. J.
Rosenberg, R. E.

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Platteville, WI

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Liska, T. L.
Soofi, A. S.

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Darr, R. K.
Kao, C. H. C.
Peng, W.
Reilly, W. R.

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Stevens Point, WI

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Hodges, D. J.
Jensen, J. E.
Kelch, P.
Palmini, D. J.
Weiser, L. A.

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Menomonie, WI

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Mandelson, D. A.
Tyson, R. J.
Zito, B. E.

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Superior, WI

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Whitewater, WI

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Parks, S. J.
Refior, E. L.
Snow, S. L.
Tesar, G.

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Menasha, WI

Kopitzke, V. A.

U. OF WIS. CTR. AT RICE LAKE
Rice Lake, WI

Brownlee, R. H.

U. OF WIS. CTR. AT SHEBOYGAN
Sheboygan, WI

Lomberg, D. E.

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Waukesha, WI

Dills, R. M.
Liu, C.

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Wausau, WI

Karkar, Y. N.

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Schredelseker, K.

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Laramie, WY

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Birch, J. W.
Bradley, E. B.
Brookshire, D. S.
Cramer, C. A.
Crocker, T. D.
Gerking, S. D.
Hansen, H. G.
Morgan, W. E.
Mutti, J. H.
Sandler, T.
Sterbenz, F. P.
Tschirhart, J. T.
Williams, J. F.

U. OF YORK
York, England

Hey, J. D.
Malcomson, J. M.
Maynard, A. K.
Williams, A. H.

U. OF ZAMBIA
Hdola, Zambia

Thorson, J. M.

U. OF ZARAGOZA
Zaragoza, Spain

Alierta, M.

U. OF ZURICH
Zurich, Switzerland

Becker, R. A.
Bohley, P.
Frey, B. S.
Janssen, M. C.
Pommerehne, W. W.
Schelbert-Syfrig, H.
Schneider, F.
Schneider, H.
Zimmermann, A. J.

UPPER IOWA U.
Fayette, IA

Longley, W. W.

UPSALA COLL.
East Orange, NJ

Englander, V. M.
Kimberland, K. G.
Moniz, J.

URSINUS COLL.
Collegeville, PA

Pilgrim, J. D.
Symons, H. C.

UTAH STATE U.
Logan, UT

Biswas, B.
Franklin, D. R.
Glover, T. F.
Godfrey, E. B.
Hansen, G. B.
Israelsen, L. D.
Jensen, B.
Keith, J. E.
Lewis, W. C.
Narayanan, R.
Roberts, N. K.
Thorne, A. C.
Whitaker, M. D.

VALDOSTA STATE COLL.
Valdosta, GA

Kushner, J. W.

VALENCIA COMMUNITY COLL.
Orlando, FL

Hise, K. W.

VALLEY CITY STATE COLL.
Valley City, ND

Crawford, J. C.

VALPARAISO U.
Valparaiso, IN

Laube, R. H.

VANDERBILT U.
Nashville, TN

Adamache, K. P.
Anderson, K. H.
Becker, C. M.
Black, S. W.
Blitz, R. C.
Burkhauser, R. V.
Fels, R.
Finegan, T. A.
Getz, M.
Hellemaim-Ashfield, J. R.
Hinshaw, C. E.
Huang, C. J.
Jung, W. S.
Maneschi, A.
Morley, S. A.
Richmond, S. B.
Rose, G. G.
Sahota, G. S.
Shahan, E. P.
Siegfried, J. J.
Stoan, F. A.
Sweeney, G. H.
Sweeney, M. J.
Tang, A. M.
Thweatt, W. O.
Tychsen, S. L.
Weingartner, H. M.
Westfield, F. M.
Whaley, R. E.
Worley, J. S.

VANIER COLL. AT STE. CROIX CAMPUS
Montreal, PQ

Nimarko, A. G.

VANIER COLL. AT SNOWDON
Montreal, PQ

Ahmad, N.

VASSAR COLL.
Poughkeepsie, NY

Brown, E. C.
Herbst, L. A.
Jehle, G. A.
Lunt, W. E.
Marshall, N. J.
Myers, M. G.
Ozmucur, S.
Rosen, F. M.
Rousseas, S. W.

VICTORIA COLL.
Victoria, TX

Burdine, F. B.
Talley, C. A.
Talley, G. F.

VICTORIA U. OF WELLINGTON
Wellington, New Zealand

Brosnan, P. A.
Evans, L. T.
Gould, J. D.
Karacaoglu, G.
Philpott, B. P.
Sheppard, D. K.

VILLANOVA U.
Villanova, PA

Burgess, F. M.
Clarke, J. J.
Cleaver, T. W.
Elek, P. S.
Gardezky, A.
Mason, S.
Mathis, E. J.
O'Donnell, L. A.
Romine, L. E.
Shrager, S. A.
Thanawala, K.
Zech, C. E.

VA. COMMONWEALTH U.
Richmond, VA

Bowman, J. H.
Campbell, T. C.
Dalton, A. H.
Harrison, W. B.
Hellmuth, W. R., Jr
Hoffer, G. E.
Lanfranco, S. L.
Moszer, M.
Reilly, R. J.
Sharshar, A. M.
Snellings, E. C.
Wetzel, J. N.
Yoo, J. H.

VA. MILITARY INSTITUTE
Lexington, VA

Blackwell, J. L.
Chang, J. L. Y.
Claiborn, E. L.
Fraley, C. E.
Hutchinson, E. B.

VA. POLY. INSTITUTE
Blacksburg, VA

Hirschhorn, E. L.

VA. POLY. INSTITUTE & STATE U.
Blacksburg, VA

Bernat, G. A., Jr
Brennan, H. G.
Buchanan, J. M.
Cox, M. W.
Friedman, D. D.
Gamber, E. N.
Gaynor, M. S.
Hassan, A. A.
Havlicek, J.
Himarios, D. D.
Hinch, M. J.
Kemp, B. A.
Klemperer, W. D.
Kramer, R. A.
Leband, D. N.
Lee, D. R.
Mandelstamm, A. B.
Meiselman, D. I.
Mitchell, G. H.
Mullin, G. E.
Norton, G. W.
Orr, D.
Patterson, D. M.
Pettengill, J. S.
Pollard, W. A.
Rankin, E. L.
Reid, J. D., Jr
Schmidt, W. E.
Thatcher, J. G.
Tideman, T. N.
Tullock, G.
Weber, W. E.

VA. STATE U.
Petersburg, VA

de, V. H.
Duke, C. C.
Joshua, M. S.
Meeks, T. J.
Moak, S. K.
Rachmel, L.
Whyte, C. D.

VOCATIONAL & INDUSTRIAL TRAINING
Singapore, Singapore

Chan, K. P.

VOORHEES COLL.
Denmark, SC

Toler, R. E.

WABASH COLL.
Crawfordsville, IN

Naylor, J. A.
Theroux, R. P.
Tiemann, T. K.

WAGNER COLL.
Staten Island, NY

De Kadt, M.

WAKE FOREST U.
Winston-Salem, NC

Frey, D. E.
Hammond, J. D.
High, S. H.
Moorhouse, J. C.
Peacock, P.
Wagstaff, J. V.
Wyzan, M. L.

WALLA WALLA COLL.
College Place, WA

Harder, F. L.

WALSH COLL. OF BUS. ADMIN.
Troy, MI

Hoffman, H. T.

WALTER & MAY REUTHER U.A.W. FAMILY EDUC. CTR.
Onsway, MI

Haener, A.

WARTBURG COLL.
Waverly, IA

Mathew, T.

WASEDA U.
Tokyo, Japan

Hiruma, F.
Kashiwazaki, T.
Tomono, N.

WASHBURN U.
Topeka, KS

Olson, R. E.

WASHINGTON & JEFFERSON COLL.
Washington, PA

Miller, R. K.
Saalbach, W. F.

WASHINGTON & LEE U.
Lexington, VA

Atwood, E. C.
Cook, J. D., Jr
Herrick, B. H.
Kaiser, C. P.
Lowry, S. T.
Phillips, C. F., Jr.

WASHINGTON COLL.
Chestertown, MD

Malone, M. S.

WASHINGTON U.
St. Louis, MO

Benham, L.
Biggs, J. H.
Daniels, L. D.
Feigenbaum, B.
Felix, D.
Greenberg, E.
Hochwald, W.
Jones, A. H.
Kalcic, B. W.
Leven, C. L.
Little, J. T.
Maloney, K. J.
Marshall, W. J.
Meadows, G. R.
Meyer, L. H.
Minsky, H. P.
Niehaus, G. R.
Nti, K. O.
Parks, R. P.
Raines, F. Q.
Sheppard, S. C.
Smirlock, M. L.
Stover, M. E.
Varvares, C. P.
Warren-Boulton, F. R.
Webster, C. E.
Weidenbaum, M. L.
Weingast, B. R.
Woodward, R. S.
Yawitz, J. B.

WASH. STATE U.
Pullman, WA

Barkley, P. W.
Berney, R. E.
Blakeslee, L.
Butcher, W. R.
Clark, E.
Douglas, E.
Duncan, G. M.
Hendriksen, E. S.
Inaba, F. S.
Iulo, W.
Joerding, W. H.
Kottke, F. J.
Leigh, D. E.
Lowinger, T. C.
McAllister, H. E.
Nelson, J. C.
Nziramasanga, M. T.

Price, D. W.
Rem, R.
Settle, J. W.
Smith, D. S.
Spencer, D. E.
Wandschneider, P. R.

WASHTENAW COMMUNITY COLL.
Ann Arbor, MI

Vass, S. T.

WAYNESBURG COLL.
Waynesburg, PA

Cowan, R. S., Jr

WAYNE STATE U.
Detroit, MI

Adelman, M. J.
Bushnell, R. C.
Fand, D. I.
Finn, T. J.
Frederick, J. R.
Freiman, M. P.
Goodman, I. B.
Haines, M. R.
Hamilton, J. L.
Kahn, M. L.
Kapil, D. P.
Karlson, S. H.
Lee, L. W.
Levin, J. H.
Long, A. L.
Mattila, J. M.
Owen, J. D.
Paauw, D. S.
Pearsall, E. S.
Roskamp, K. W.
Rossiter, R. D.
Santiago, C. E.
Seltzer, L. H.
Shaw, R. E.
Smyth, D. J.
Spencer, M. H.
Stern, M.
Sung, C. H.
Thompson, W. R.
Thomson, M. H.
Tountas, S. D.

WEBER STATE COLL.
Ogden, UT

Chi, W.
Fuller, D. A.
Smith, W. J.

WELLESLEY COLL.
Wellesley, MA

Baum, S. R.
Bell, C. S.
Case, K. E.
Clemence, R. V.
Goldman, M. I.
Grant, J. H.
Matthaei, J. A.
Morrison, R. J.
Nichols, L. M.

WESLEYAN U.
Middletown, CT

Barber, W. J.
Chenault, L.
Halberg, J. G.
Irvine, F. O.
Kilby, P.
Lebergott, S.
Lovell, M. C.
Miller, R. A.
Moore, B. J.
Whitin, T. M.
Yohe, G. W.

WEST AUSTRALIA INSTITUTE OF TECHNOL.
South Bentley, Australia

Greig, R. A.
Karasinski, J. M.

WESTCHESTER COMMUNITY COLL.
Valhalla, NY

Allegretti, E. V.
Rendich, M. F.

WEST CHESTER STATE COLL.
West Chester, PA

Dunleavy, K. G.
Green, A. W.
Naggar, T. R.
Schooler, E. W.

WESTERN CAROLINA U.
Cullowhee, NC

Schreiber, M. M.
Shin, K.
Spencer, A. H.
Wade, J. A.

WESTERN CONN. STATE COLL.
Danbury, CT

Dente, L. A.
Kalla, M. S.

WESTERN ILL. U.
Macomb, IL

Blewett, R. A.
Kaul, T. K.
Marlin, J. W.
Marx, K. B.
Novak, D. S.
Rao, V.
Torgerson, M. S.
Walzer, N. C.
Webb, J. L.
Yunker, J. A.

WESTERN KY. U.
Bowling Green, KY

Cann, K. T.
Needham, D.
Oppitz, R. J.
Pulsinelli, R. W.
Russell, K. P.
Wassom, J. C.

WESTERN MD. COLL.
Westminster, MD

Claycombe, R. J.
Law, A. D.
Seidel, E. A.

WESTERN MICH. U.
Kalamazoo, MI

Aker, U.
Caruso, P. P.
Gardner, W. D.
Harik, B. E.
Ho, A. K.
Hoffman, E. P.
Howard, J. M.
Junker, L. J.
Ross, M. H.
Sichel, W.
Wend, J. S.
Zelder, R. E.

WESTERN MONT. COLL.
Dillon, MT

O'Connor, W. C.

WESTERN NEW ENGLAND COLL.
Springfield, MA

Andrulis, J. A.
Meeropol, M. A.

WESTERN ORE. STATE COLL.
Monmouth, OR

Finster, R. D.
Singh, A.

WESTERN STATE COLL. OF COLO.
Gunnison, CO

Arsenovich, D.
Wallace, M. S.

WESTERN WASH. U.
Bellingham, WA

Johnson, H. T.
Mitchell, H. E.
Murphy, D. R.
Nelson, D. M.

WESTFIELD STATE COLL.
Westfield, MA

Bellico, R.

W. GA. COLL.
Carrollton, GA

Dickey, S. W.
Gustafson, L. V.
Karsten, S. G.
Sav, G. T.

WEST LIBERTY STATE COLL.
West Liberty, WV

Donnelly, E. H.
Polak, G.

WEST LOS ANGELES COLL.
Culver City, CA

Shin, P. Y. H.

WESTMAR COLL.
Le Mars, IA

Kang, C. W.

WESTMINSTER COLL.
Fulton, MO

Barrett, A.

WESTMINSTER COLL. (PA.)
New Wilmington, PA

Fischmar, D. E.

WESTMINSTER COLL. (UTAH)
Salt Lake City, UT

Seidelman, J. E.

WESTMONT COLL.
Santa Barbara, CA

Bartel, R. J.
Morgan, P. L.

W. TEX. STATE U.
Canyon, TX

Duman, B. L.
Early, A.

W.VA. COLL. OF GRAD. STUDIES
Institute, WV

Figura, R. S.

W.VA. STATE COLL.
Institute, WV

Henderson, S. R.

W.VA. U.
Morgantown, WV

Alvis, V. Q.
Bell, L. C.
Clark, J. A.
Culler, S. D.
Cushing, B. J.
Daniel, R. P.
Fogarty, M. S.
Hawley, C. B.
Holliday, R. E.
Hwang, M. J.
Jenab, P.
Kymn, K. O.
Labys, W. C.
Leyden, D. R.
Mann, P. C.
Miernyk, W. H.
Misra, S.
Newcomb, R. T.
Page, W. P.
Thompson, J. H.
Witt, T. S.
Zeller, F. A.

W.VA. WESLEYAN COLL.
Buckhannon, WV

Bayard, F.

WHEATON COLL. (ILL.)
Wheaton, IL

Ewert, N. J.
Helteman, J.

WHEATON COLL. (MASS.)
Lexington, MA

Kahne, H.
Weil, G.
Yoo, J.

WHEATON COLL. (VA.)
Alexandria, VA

Walgreen, J. A.

WHEELING COLL.
Wheeling, WV

Hamilton, K. N.

WHITMAN COLL.
Walla Walla, WA

Knopf, K. A.
Philpot, G. A.
Shepherd, J. F.
Stevens, D.

WHITTIER COLL.
Whittier, CA

Laine, C. R.
Overturf, S. F.
Woirol, G. R.

WICHITA STATE U.
Wichita, KS

Cho, D. W.
Christenson, D. D.
Clark, J. E.
Duell, D. C.
Fagerlund, E. A.
McDougall, G. S.
Merrifield, D. E.
Perline, M. M.

Pfannestiel, M.
Snyder, N. M.
Terrell, W. T.
Webb, S. C.
White, R. D.

WIDENER U.
Chester, PA

Johnson, M. M.
Meli, J. T.
Ozatalay, S.
Rosko, M. D.
Waldauer, C.
Zahka, W. J.

WILBUR WRIGHT COLL.
Evanston, IL

Senn, P. R.

WILFRID LAURIER U.
Waterloo, ON

Gillen, D. W.
Marr, W. L.
McCready, D. J.
Raj, B.
Siklos, P. L.
Stewart, M. D.
Venton, J. P.

WILKES COLL.
Wilkes-Barre, PA

Taylor, W. A.

WILLAMETTE U.
Salem, OR

Hanson, J. S.
Hibbard, T. H.

WILLIAM JEWELL COLL.
Liberty, MO

Cook, M. T.

WILLIAM PATERSON COLL. OF N.J.
Wayne, NY

Dayhim, H.
Dorai, G. C.
Harold, L.
Leung, C. K.
Tonak, E. A.

WILLIAMS COLL.
Williamstown, MA

Alston, L. J.
Bolton, R. E.
Bradburd, R. M.
Bruton, H. J.
Clark, P. G.
Epstein, G. A.
Jha, R.
Jurewitz, J. L.
Kershaw, J. A.
Lewis, S. R.
McNally, K. V.
McPherson, M.
Schapiro, M. O.
Schor, J. B.
Sheehan, J. B.
Van Duyne, C. I.
White, J. R.
Williams, R. C.
Winston, G. C.

WILMINGTON COLL.
Wilmington, OH

Giesbrecht, M. G.

WINDHAM COLL.
Putney, VT

Faulkender, R. E.

WINGATE COLL.
Wingate, SC

Lim, J. D.

WINONA STATE U.
Winona, MN

Hunter, D. J.
Rieder, M. E.

WINTHROP COLL.
Rock Hill, SC

Stone, G. L.

WITTENBERG U.
Springfield, OH

Goulet, J. C.
Petruska, D. A.
Simmons, F. B.

WOFFORD COLL.
Spartanburg, SC

Afshar, K.
Touchstone, S. K.

WORCESTER POLY. INSTITUTE
Worcester, MA

Graubard, L. S.
Onorato, N. L.
Woods, D. W.

WRIGHT STATE U.
Dayton, OH

Chao, J. T. C.
Fabrycy, M. Z.
Fichtenbaum, R. H.
Maxwell, C. E.
Renas, S. M.
Verdon, W. A.
Wang, L. F. S.
Wechsler, B.

XAVIER U.
Cincinnati, OH

Hailstones, T. J.
Hermon, B. M.
Jankowske, W. C.
Kuzina, S. G.
Olson, J. F.
Webb, P. B.
Weinberg, D. R.
Zimmerman, R. O.

YALE U.
New Haven, CT

Bernstein, M. A.
Blau, D. M.
Bradford, C. I., Jr
Broude, H. W.
Campbell, J. Y.
Diaz-Alejandro, C. F.
Donahoo, K. K.
Downing, D. A.
Ely, C. C.
Eckstein, Z.
Evenson, R. E.
Fair, R. C.
Felgran, S. D.
Fishlow, A.
Hu, O. S. Y.
Katseli-Papaefstratiou, L. T.
Keeton, W. R.
Kelley, J.
Klevorick, A. K.
Koopmans, T. C.
Kotlikoff, L. J.
Kwerel, E. R.
Kyriacou, L.
Lardy, N. R.
Levin, R. C.
Lindblom, C. E.
Malkiel, B. G.
Miller, J. P.
Montias, J. M.
Murnane, R. J.
Nelson, R. R.
Nordhaus, W. D.
Orazem, P.
Orcutt, G. H.
Oster, S. M.
Patrick, H. T.
Peck, M. J.
Priest, G. L.
Ranis, G.
Reiss, P. C.
Rennhack, R. K.
Reynolds, L. G.
Rose-Ackerman, S.
Ross, S.
Ruggles, N. D.
Ruggles, R.
Scarf, H.
Schoenholtz, K. L.
Schultz, T. P.
Shubik, M.
Sick, G. A.
Smith, C. I.
Smitka, M. J.
Srinivasan, T. N.
Stern, S. N.
Struckmeyer, C. S.
Thorne, E. D.
Tobin, J.
Tufte, E. R.
Verleger, P. K.
Wakasugi, R.
Weir, D. R.
Winter, S. G.
Wippern, R. F.
Wolpin, K. I.
Wright, B. D.

YEONSEI U.
Seoul, South Korea

Lee, M. S.

YESHIVA U.
New York, NY

Forkosch, M. D.

YOKOHAMA NAT. U.
Yokohama, CA

Ishii, Y. Y.
Okuno, M.

YONSEI U.
Seoul, South Korea

Han, S.
Im, I.
Jung, C.
Yoon, k. J.
Yoon, S. B.

YORK COLL. OF CUNY
Jamaica, NY

Althaus, P. G.
Kraus, J.

YORK U.
Downsview & Toronto, ON

Anderson, L. D.
Beare, J. B.
Borins, S. F.
Burstein, M.
Buttrick, J. A.
Daly, D. J.
Evans, J. C.
Fallis, G. B.
Friedland, S.
Glenday, G.
Jordan, W. A.
Kings, J. B.
Lazar, F.
Lefeber, L.
Litvak, I. A.
MacDonald, H. I.
McKechnie, G. H.
McQueen, D. L.
Paraskevopoulos, C. C.
Plourde, C. G.
Reinhardt, P. G.
Robinson, A. J.
Savary, J. R.
Walker, M. A.
Warner, S. L.
Wolf, B. M.
Zohar, U.

YOUNGSTOWN STATE U.
Youngstown, OH

Hahn, P. J.
Mackall, E. P.
Mehra, J.
Psenicka, C. O.
Stocks, A. H.
Wegner, R. C.

Supplementary Information and Statistical Summaries

Officers of the Association, 1975–81

Nominating Committee Members and Editorial Boards

Honors and Awards

Annual Meetings

Affiliated Organizations

Other Economic Associations

Analysis of Membership and Subscriptions

Officers of the Association: 1975–1981

*Chronological List**

Year	*President*	*President-elect*	*Vice-Presidents*	*Elected Members of Executive Committee*
1975	Robert Aaron Gordon	Franco Modigliani	Martin Bronfenbrenner Charles L. Schultze	Irma Adelman Robert L. Heilbroner Andrew F. Brimmer Paul M. Sweezy Carolyn Shaw Bell Burton A. Weisbrod
1976	Franco Modigliani	Lawrence R. Klein	Barbara R. Bergmann Harry G. Johnson	Andrew F. Brimmer Paul M. Sweezy Carolyn Shaw Bell Burton A. Weisbrod Edmund S. Phelps Alice M. Rivlin
1977	Lawrence R. Klein	Jacob Marschak†	Robert Eisner Anne O. Krueger	Carolyn Shaw Bell Burton A. Weisbrod Edmund S. Phelps Alice M. Rivlin Robert J. Lampman Marc Nerlove
1978	Tjalling Koopmans	Robert M. Solow	Edward F. Denison Joseph A. Pechman	Edmund S. Phelps Alice M. Rivlin Robert J. Lampman Marc Nerlove Robert W. Clower Marina v.N. Whitman
1979	Robert M. Solow	Moses Abramovitz	Irma Adelman Jack Hirshleifer	Robert J. Lampman Marc Nerlove Robert W. Clower Marina v.N. Whitman Henry J. Aaron Zvi Griliches
1980	Moses Abramovitz	William J. Baumol	Carl F. Christ H. Gregg Lewis	Robert W. Clower Marina v.N. Whitman Henry J. Aaron Zvi Griliches Martin Feldstein Robert E. Lucas
1981	William J. Baumol	Gardner Ackley	Otto Eckstein Alice M. Rivlin	Henry J. Aaron Zvi Griliches Martin Feldstein Robert E. Lucas Elizabeth E. Bailey Robert J. Gordon

*For the years 1886–1952, see the 1956 *Handbook*, pages 454–63; 1953–59, the 1969 *Handbook*, pages 581–82; 1960–74, the 1978 *Survey*, pages 491–493.

†Died before becoming President.

*Alphabetical List***

Name	*President-elect and President*	*Vice-President*	*Executive Committee*
Aaron, Henry	.....	.....	1979–81
Abramovitz, Moses	1979–80	1969	1965–67
Ackley, Gardner	1981–82	1963	.....
Adelman, Irma	.....	1979	1973–75
Arrow, Kenneth J.	1972–73	.....	1967–69
Bailey, Elizabeth E.	.....	.....	1981–83
Baumol, William J.	1980–81	1967	1963–65
Bell, Carolyn Shaw	.....	.....	1975–77
Bergmann, Barbara R.	.....	1976	.....
Brimmer, Andrew F.	.....	.....	1974–76
Bronfenbrenner, Martin	.....	1975	.....
Christ, Carl F.	.....	1980	.....
Clower, Robert W.	.....	.....	1978–80
Denison, Edward F.	.....	1978	.....
Eckstein, Otto	.....	1981	1968–70
Eisner, Robert	.....	1977	1971–73
Feldstein, Martin	.....	.....	1980–82
Gordon, Robert Aaron	1974–75	1960	1950–52
Gordon, Robert J.	.....	.....	1981–83
Griliches, Zvi	.....	.....	1979–81
Heilbroner, Robert L.	.....	.....	1973–75
Hirshleifer, Jack	.....	1979	.....
Johnson, Harry G.	.....	1976	1964–66
Klein, Lawrence R.	1976–77	1973	1966–68
Koopmans, Tjalling	1978	1966	.....
Krueger, Anne O.	.....	1977	.....
Lampman, Robert J.	.....	.....	1977–79
Lewis, H. Gregg	.....	1980	.....
Lucas, Robert E.	.....	.....	1980–82
Marschak, Jacob	1977†	.....	.....
Modigliani, Franco	1975–76	1971	1967–69
Nerlove, Marc	.....	.....	1977–79
Pechman, Joseph A.	.....	1978	1972–74
Phelps, Edmund S.	.....	.....	1976–78
Rivlin, Alice M.	.....	1981	1976–78
Schultze, Charles L.	.....	1975	1969–71
Solow, Robert M.	1978–79	1968	1964–66
Sweezy, Paul M.	.....	.....	1974–76
Weisbrod, Burton A.	.....	.....	1975–77
Whitman, Marina v. N.	.....	.....	1978–80

**Years denote term of office, not date of election. Earlier years also shown for those individuals who have served since 1975.
†Died before assuming Presidency.

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Richard W. Parks
Leonard A. Rapping
Barbara Reagan
Christopher Sims

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Duran Bell
Marianne Ferber
Jack Hirshleifer
Leonard Rapping
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Ralph W. Pfouts

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Rachel McCulloch
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Lester Thurow
Murray L. Weidenbaum

1981 Carl F. Christ, Chair
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Robert Dorfman
Juanita Kreps
Lester Lave
Lester Thurow
Robert Willig

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American Economic Review

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Martin S. Feldstein
Ann F. Friedlaender
Stephen M. Goldfeld
Robert J. Gordon
Robert E. Hall
Bent Hansen
James R. Melvin
William D. Nordhaus
Leonard A. Rapping
Stephen Resnick
Anna J. Schwartz
Jerome Stein
Joseph E. Stiglitz
S. C. Tsiang
Finis Welch
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Eugene F. Fama
Martin S. Feldstein
Robert J. Gordon
Bent Hansen
David Laidler
James R. Melvin
William D. Nordhaus
Stephen Resnick
Anna J. Schwartz
Frank P. Stafford
Jerome Stein
S. C. Tsiang
Finis Welch
Marina v.N. Whitman

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Laurits R. Christensen
Eugene F. Fama
Martin S. Feldstein
Robert J. Gordon
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James R. Melvin
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Frank P. Stafford
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David F. Bradford
Laurits R. Christensen
Eugene F. Fama
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Robert J. Gordon
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James R. Melvin
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Frederick M. Scherer
Anna J. Schwartz
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Jerome Stein

1979 Irma Adelman
Albert Ando
Elizabeth E. Bailey
David P. Baron
Robert J. Barro
David F. Bradford
Laurits R. Christensen
Rudiger Dornbusch
Martin S. Feldstein
David Laidler
William H. Oakland
Richard W. Roll
F. M. Scherer
A. Michael Spence
Frank P. Stafford
Jerome Stein
William S. Vickrey
S. Y. Wu

1980 Albert Ando
Elizabeth E. Bailey
Pranab K. Bardhan
David E. Bradford
Peter A. Diamond
W. Erwin Diewert
Rudgier Dornbusch
Martin S. Feldstein
William H. Oakland
Michael Parkin
Roy Radner
Richard W. Roll
F. M. Scherer
Nancy L. Schwartz
A. Michael Spence
Jerome Stein
William S. Vickrey
S. Y. Wu

1981 Albert Ando
Pranab K. Bardhan
Peter A. Diamond
W. Erwin Diewert
Rudiger Dornbusch
Herschel I. Grossman
Peter W. Howitt
Anne O. Krueger
William H. Oakland
Michael Parkin
Roy Radner
Richard W. Roll
Nancy L. Schwartz
James P. Smith
A. Michael Spence
William S. Vickrey
Robert D. Willig
S. Y. Wu

*For the years 1934–53, see the 1956 *Handbook*, pages 465–67; 1954–59, the 1969 *Handbook*, pages 584–85; 1960–74, the 1978 *Survey*, pages 497–98.

Journal of Economic Literature

1975 Moses Abramovitz
Marcus Alexis
Martin Bronfenbrenner
Anne P. Carter
Arthur S. Goldberger
Anne O. Krueger
Thomas Mayer
Allan H. Meltzer
Ryuzo Sato
Tibor Scitovsky
William S. Vickrey

1976 Moses Abramovitz
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Anne P. Carter
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Arthur S. Goldberger
James K. Kindahl
Thomas Mayer
Michio Morishima
Ryuzo Sato
Tibor Scitovsky
William S. Vickrey
Charles Z. Wilson, Jr.

1977 Moses Abramovitz
Solomon Fabricant
George R. Feiwel
Arthur S. Goldberger
James K. Kindahl
Thomas Mayer
William H. Miernyk
Michio Morishima
Michael J. Piore
Barbara B. Reagan
Ryuzo Sato
Charles Z. Wilson, Jr.

1978 Solomon Fabricant
George R. Feiwel
James K. Kindahl
David E. W. Laidler
Harvey Leibenstein
Daniel L. McFadden
William H. Miernyk
Michio Morishima
Michael J. Piore
Roger L. Ransom
Barbara B. Reagan
Charles Z. Wilson, Jr.

1979 Edwin Burmeister
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David E. W. Laidler
Robert J. Lampman
Harvey Leibenstein
Daniel L. McFadden
William H. Miernyk
Michael J. Piore
Roger L. Ransom
Barbara B. Reagan
E. Roy Weintraub

1980 Nicholas W. Balabkins
Edwin Burmeister
Donald J. Harris
John W. Kendrick
David E. W. Laidler
Robert J. Lampman
Harvey Leibenstein
Daniel L. McFadden
Roger L. Ransom
Isabel V. Sawhill
E. Roy Weintraub

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Alan S. Blinder
Edwin Burmeister
Donald J. Harris
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Roger G. Noll
Michael Rothschild
Isabel V. Sawhill
E. Roy Weintraub
Finis Welch

Honors and Awards

DISTINGUISHED FELLOWS

In 1965 the award of Distinguished Fellow was instituted. The following have received this award:

1965 Edward H. Chamberlin
Harold Hotelling

1966 Abba P. Lerner

1967 Jacob Marschak

1968 Lloyd A. Metzler

1969 Ludwig von Mises
Alexander Gerschenkron

1970 William Arthur Lewis

1971 Nicholas Georgescu-Roegen
Tjalling Koopmans

1972 Robert A. Gordon
Carl S. Shoup

1973 Tibor Scitovsky

1975 Moses Abramovitz

1976 Oskar Morgenstern
Herbert A. Simon

1977 Harry G. Johnson
Leonid Hurwicz

1978 Richard A. Musgrave
William S. Vickrey

1979 Margaret G. Reid
Ronald H. Coase

1980 Charles P. Kindleberger
Solomon Fabricant

1981 Edward F. Denison
H. Gregg Lewis

HONORARY MEMBERS

Maurice Allais *1976* ..... France
Roy G. D. Allen *1976* ..... United Kingdom
Gottfried Bombach *1976* ..... Switzerland
Jacques Dreze *1976* ..... Belgium
Herbert Giersch *1976* ..... Germany
Eugenio Gudin *1962* ..... Brazil
Trygve Haavelmo *1975* ..... Norway
Hrothgar Habakkuk *1976* ..... United Kingdom
Roy Harrod *1950* ..... United Kingdom
Friedrich A. Hayek *1975* ..... Austria
John Hicks *1950* ..... United Kingdom
Leif Johannsen *1976* ..... Norway
Nicholas Kaldor *1975* ..... United Kingdom
Janos Kornai *1976* ..... Hungary
Assar Lindbeck *1976* ..... Sweden
Erik Lundberg *1962* ..... Sweden
Edmond Malinvaud *1975* ..... France
James Meade *1962* ..... United Kingdom
Michio Morishima *1976* ..... United Kingdom
Gunnar Myrdal *1947* ..... Sweden
Bertil Ohlin *1947* ..... Sweden
Ugo Papi *1962* ..... Italy
Don Patinkin *1975* ..... Israel
Francois Perroux *1962* ..... France
Raul Prebisch *1962* ..... Argentina
K. N. Raj *1976* ..... India
Lionel Robbins *1947* ..... United Kingdom
Joan Robinson *1950* ..... United Kingdom
René Roy *1976* ..... France
T. N. Srinivan *1976* ..... India
Richard Stone *1976* ..... United Kingdom
Jan Tinbergen *1950* ..... Netherlands
Shigeto Tsuru *1976* ..... Japan
Hirofumi Uzawa *1976* ..... Japan
Herman Wold *1976* ..... Sweden

AWARDS

In 1947 the award of two honorary medals was instituted. The Walker medal is awarded once every five years and the Clark medal every two years. Recipients of these awards to date are:

Francis A. Walker Medal

1947 Wesley C. Mitchell

1952 John Maurice Clark

1957 Frank H. Knight

1962 Jacob Viner

1967 Alvin H. Hansen

1972 Theodore W. Schultz

1977 Simon Kuznets

John Bates Clark Medal

1947 Paul A. Samuelson

1949 Kenneth E. Boulding

1951 Milton Friedman

1953 No award

1955 James Tobin

1957 Kenneth J. Arrow

1959 Lawrence R. Klein

1961 Robert M. Solow

1963 Hendrik S. Houthakker

1965 Zvi Griliches

1967 Gary S. Becker

1969 Marc Leon Nerlove

1971 Dale W. Jorgenson

1973 Franklin M. Fisher

1975 Daniel McFadden

1977 Martin S. Feldstein

1979 Joseph E. Stiglitz

1981 A. Michael Spence

Annual Meetings

Year	City	Local Arrangements Chair	Attendance A.E.A.	Attendance Total
1975	Dallas	Ralph T. Green	2,942	3,885
1976	Atlantic City	Edward G. Boehne	2,726	4,279
1977	New York	Richard G. Davis	3,808	6,381
1978	Chicago	Karl Scheld, Roby Sloan	1,529	2,997
1979	Atlanta	Harry Brandt	2,671	4,640
1980	Denver	Thomas E. Davis	1,313	2,516
1981	Washington, D.C.	Andrew F. Brimmer		
1982	New York	Peter Fousek		
1983	San Francisco			
1984	Dallas			
1985	New York			

A tabulation of "Statistics of Annual Meetings" from 1885 to 1910 may be found in the papers and discussions on the occasion of the twenty-fifth anniversary of the Association, published in the "Third Series" of the publications of the Association (Vol. XI, 1910, No. 1, pages 92–93).This tabulation gives not only the date and place of meeting but also indicates main subjects discussed and the number of members of the Association. For the years 1910–35, see the 1948 *Handbook*, page 306; 1936–59, the 1969 *Handbook*, page 588; 1960–74, the 1978 *Survey*, page 501.

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New York, New York 10022

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Washington, D.C. 20036

INTERNATIONAL ECONOMIC ASSOCIATION

4 rue de Chevreuse
75006 Paris, France

JOINT COUNCIL ON ECONOMIC EDUCATION

1212 Avenue of the Americas
New York, New York 10036

NATIONAL BUREAU OF ECONOMIC RESEARCH, INC.

1050 Massachusetts Avenue
Cambridge, Massachusetts 02138

SOCIAL SCIENCE RESEARCH COUNCIL

605 Third Avenue
New York, New York 10016

Other Economic Associations

The following is a list of other associations which might be of interest to members of the American Economic Association and the economics profession. The names and addresses of the secretaries or administrative officers are given to facilitate contacting them for further information.

AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

Professor Sydney James (515) 294–8700
Department of Economics
Iowa State University
Ames, Iowa 50011

AMERICAN FINANCE ASSOCIATION

Professor Robert G. Hawkins (212) 285–6040
Graduate School of Business Administration
New York University
100 Trinity Place, Room 1006
New York, New York 10006

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Mr. Cornelius J. Dwyer (202) 633–8711
4600 Connecticut Avenue, NW - Suite 432
Washington, D.C. 20008

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Director Campus Services
APPME
9 East 40th Street
New York, New York 10016

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University of South Carolina
Columbia, South Carolina 29208

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Department of Economics
University of Nebraska
Lincoln, Nebraska 68510

ASSOCIATION FOR SOCIAL ECONOMICS

Professor Edward J. O'Boyle (318) 257–3701
College of Administration & Business
Louisiana Tech University
P.O. Box 10318 Tech Station
Ruston, Louisiana 71272

ASSOCIATION FOR THE STUDY OF GRANTS ECONOMY

Professor Janos Horvath (317) 283-9552
Holcomb Research Institute
Butler University
Indianapolis, Indiana 46208

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Edison Electric Institute
1111 19th Street, NW
Washington, D.C. 20036

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Department of Economics
Manhattan College
Riverdale, New York 10471

ASSOCIATION OF PROPERTY AND CASUALTY INSURANCE ECONOMISTS

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c/o National Council on Compensation Insurance
One Penn Plaza
New York, New York 10001

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Lancaster, Pennsylvania 17604

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Evanston, Illinois 60201

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University of Southern California
Los Angeles, California 90007

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Mathematica Policy Research, Inc.
905 University Avenue, Room 203
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Bloomington, Indiana 47402

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California State University
Long Beach, California 90840

WESTERN TAX ASSOCIATION

Professor R. Bruce Billings (602) 626-1675
Department of Economics
University of Arizona
Tuscon, Arizona 85721

Analysis of Membership and Subscriptions

MEMBERSHIP CLASSES

(End of Year)

	1941	*1946*	*1953*	*1956*	*1963*	*1966*	*1969*	*1974*	*1978*	*1980*
Class of Membership										
Regular	3,250	4,376	6,682	7,634	10,152	12,820	16.036	14,544	15,698	16,219
Junior	124	153	409	533	1,331	1,819	2,308	3,135	1,857	1,811
Life	37	31	62	78	228	254	276	342	389	383
Honorary	19	13	21	18	18	17	16	14	35	33
Family	19	68	121	129	147	196	274	313	307	331
Complimentary	13	21	40	58	97	123	151	418	615	624
Total Members	3,462	4,662	7,335	8,450	11,973	15,229	19,061	18,766	18,901	19,401
Subscribers	1,319	2,161	2,844	3,135	4,306	6,075	7,025	7,353	6,893	7,094
Total Members and Subscribers	4,781	6,823	10,179	11,585	16,279	21,304	26,086	26,119	25,794	26,495

*For the years 1886–1959, see the 1969 *Handbook*, pages 593–94.

GEOGRAPHICAL ANALYSIS OF MEMBERSHIP AND SUBSCRIPTIONS

Based on Journal Label Analysis
April 8, 1981**

NORTHEAST	*ME*	*NH*	*VT*	*MA*	*RI*	*CT*	*NY*	*DE*	*PA*	*NJ*	*MD*	*WV*	*DC*	*Total*
Members/Subscribers	57	81	40	934	78	337	2,090	62	856	625	654	59	1,427	7,300
MIDDLE	*OH*	*MI*	*IN*	*WI*	*MN*	*IA*	*MO*	*IL*						
Members/Subscribers	499	532	302	314	224	137	234	920	...	...	...	...	...	3.162
SOUTHEAST	*TN*	*NC*	*MS*	*VA*	*KY*	*SC*	*GA*	*AL*	*AR*	*FL*	*LA*			
Members/Subscribers	203	306	48	1,142	108	115	203	123	55	329	129	...	...	2,761
SOUTHWEST	*OK*	*TX*	*NM*	*AZ*	*NV*									
Members/Subscribers	96	520	62	125	19	...	...	...	...	...	...	...	...	822
PACIFIC	*AK*	*CA*	*HI*	*OR*	*WA*									
Members/Subscribers	25	1,582	59	136	275	...	...	...	...	...	...	...	...	2,077
NORTHWEST	*ND*	*SD*	*NE*	*KS*	*MT*	*CO*	*WY*	*ID*	*UT*					
Members/Subscribers	23	31	60	127	33	207	23	27	57	...	...	...	...	588
POSSESSIONS	*PR*	*VI*	*PI*											
Members/Subscribers	73	4	5	...	...	...	...	...	...	...	...	...	...	82
OTHER	*Can*	*PUAS*	*Foreign*											
Members/Subscribers	1,171	576	4,631	...	...	...	...	...	...	...	...	...	...	6,378

SUMMARY

	N.E.	*Middle*	*S.E.*	*S.W.*	*Pacific*	*N.W.*	*Posses-sions*	*U.S. Total*	*Other*	*Total*
Members/Subscribers	7,300	3,162	2,761	822	2,077	588	82	16,792	6,378	23,170

**For selected past years, see the 1969 *Handbook*, page 596; 1974 *Survey*, page 506.

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Les Carson

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Jerry Hamsmith

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Sherman, TX
Lee Van Zant

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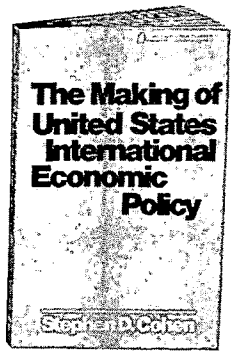

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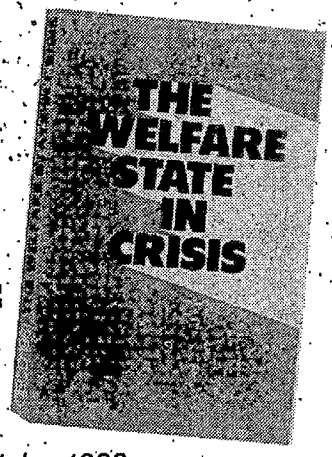

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